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WATERTOWN ARSENAL  
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INVENTORY

EXPERIMENTAL REPORT

NO WAL 710/783

MAR 11 1958

LAST PAGE

DATA, INVESTIGATIONS, TESTS, AND OTHER INFORMATION CONCERNING THE DESIGN, MANUFACTURE, AND TESTS OF THE PROJECTED AIRCRAFT ENGINE.

U.S. AIR FORCE REPORT OF INVESTIGATION PRELIMINARY TO DESIGN OF AIRCRAFT ENGINE.

BY

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Watertown Arsenal Laboratory  
Report No. WAL 710/783  
Problem B-4.78

20 November 1945

CAST ARMOR

Correlation Between Metallurgical Properties of Several 1" and 2"  
Cast Armor Samples and Their Resistance to Various Degrees  
of Ballistic Shock

OBJECT

To determine the metallurgical characteristics of 1" and 2" cast armor samples after subjection to various degrees of ballistic shock, and, by the application of analytical methods devised at this laboratory, to determine the optimum conditions of ballistic shock testing for discrimination between material of good and poor metallurgical properties.

CONCLUSIONS

The requirements for shock resistance of 1" and 2" cast armor plates submitted under Specification AXS-492-5 should reflect the following determinations:

- a. The projectiles used should be the 57 mm. proof projectile, T1, for 1" plates and the 105 mm. proof projectile, T8, for 2" plates;
- b. The incident velocity for both projectiles should be  $1030 \pm 15$  feet-per-second;
- c. The criterion of success should be the ability of the armor to resist cracking in any degree.

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## INTRODUCTION

In response to a request of the Ordnance Research Center<sup>1</sup>, a metallurgical examination of several 1" and 2" cast armor plates which had been subject to ballistic shock tests with 57 mm. and 105 mm. proof projectiles, respectively, in an attempt to develop an adequate ballistic shock test for incorporation into Specification AXS-492-5, was undertaken at this laboratory.

The criterion of success under these shock tests revolved around the ability of the plates to resist "excessive" cracking and/or Army complete penetration at a prescribed velocity<sup>2,3</sup>.

Results of the metallurgical tests on those plates indicated a very poor correlation between their metallurgical properties and their success under the ballistic tests as judged under the above criterion, and it was the opinion of this laboratory<sup>4</sup> that the prescribed shock tests were not satisfactory for incorporation into Specification AXS-492-5.

Meanwhile, before transmittal of that report to the Ordnance Research Center had been effected, additional tests of 1" and 2" cast armor samples had been completed<sup>5,6</sup> and subsequently samples from those tests were forwarded to this laboratory with a request for metallurgical evaluation<sup>7</sup>.

During a visit to the Ordnance Research Center by a representative of this laboratory near the end of July 1945, it was contended that a better correlation might exist between the metallurgical properties of these plates and their ballistic integrity as judged by their ability to resist any cracking under impact of proof projectiles at a prescribed velocity.

As a preliminary investigation of this contention, samples which were extremely successful or extremely unsuccessful under such a test were examined metallurgically and a good correlation was indicated<sup>8</sup>.

The present report is an evaluation of the correlation between the metallurgical properties of the samples and their success under the various tests as judged by various criteria.

## TEST PROCEDURE

The metallurgical examination included the following tests:

- a. Fibre fracture tests;<sup>9</sup>
- b. Cross sectional Brinell hardness survey;
- c. V-notch Charpy impact tests.

Sections, 6"x12"x2" and 4"x8"x1", were notched by flame cutting in from the middle of the two longer sides and were fractured under the impact of a steam forge hammer. A one-half inch thick section cut from the middle of one of the fractured halves of each sample was surface ground. Brinell hardness surveys were made on the cross sectional surfaces, after which

two V-notch Charpy impact specimens were machined from each section from positions halfway between the surface and the center in the case of the 1" thick plates and from near the center of the 2" thick plates. One impact specimen from each plate was tested at +70°F, and the other at -40°F.

The results of these tests are recited in Tables I and II, for 1" and 2" plates, respectively.

The results of the ballistic tests conducted at the Ordnance Research Center have been summarized in Tables III and IV, for 1" and 2" plates, respectively.

#### DATA AND DISCUSSION

The shock which may be transmitted to armor in service may originate from many sources.

The metallurgical properties which are desirable for general resistance to shock are well known and their presence may be determined by well established tests.

A specific shock test, to be valid, therefore, must produce results which correlate well with the results of metallurgical tests.

In this report certain unique methods have been developed to determine the correlation between metallurgical and ballistic characteristics of the subject plates.

Upon the completion of the metallurgical tests described above, their results, without reference to ballistic behavior, were submitted to an experienced armor metallurgist for evaluation. On the basis of their possession, or lack, of the desirable metallurgical characteristics—(a tempered martensitic structure, purely fibrous fracture, and high Charpy impact value)—the rating "Good", "Borderline +," "Borderline -," or "Poor" was given each sample as it appears in Tables I and II.

(Whether or not a specific Charpy impact value is considered adequate depends upon the hardness of the sample. A schematic representation of the expected relationship between the Charpy impact value of a given steel with a microstructure of tempered martensite and its hardness is given in Figure 8.)

By means of these unbiased metallurgical ratings, there thus became available the basis for determination of correlations between the metallurgical characteristics of these samples and their ability to satisfy the requirements of the various tests.

The firings at the Ordnance Research Center had been conducted at three different levels of severity for each projectile caliber (or armor thickness), as follows:

57 mm. Proof Projectile T1 against 1" plate at 900 f/s.  
57 mm. Proof Projectile T1 against 1" plate at 1000 f/s.  
57 mm. Proof Projectile T1 against 1" plate at 1100 f/s.

105 mm. Proof Projectile T8 against 2" plate at 1000 f/s.  
105 mm. Proof Projectile T8 against 2" plate at 1100 f/s.  
105 mm. Proof Projectile T8 against 2" plate at 1200 f/s.

The results of these tests appear in Tables III and IV, for 1" and 2" plates, respectively.

Success or failure of any plate under each of these tests can be judged from the standpoint of any of at least five criteria: its ability to resist—

- a. Army complete penetration<sup>10</sup>.
- b. Cracking in any degree.
- c. Excessive cracking.
- d. Both (a) and (b).
- e. Both (a) and (c).

The results of the ballistic tests, as set out in Tables III and IV, have been represented in Tables V and VI, respectively, as judged by the above criteria.

The use of a criterion of shock resistance incorporating the ability of a plate to withstand Army complete penetration at a given velocity has always been considered by this laboratory as unsound, in that successful resistance to complete penetration (Army) is brought about by the possession of metallurgical characteristics irrelevant to and even inconsistent with those characteristics which are requisite for superior shock resistance.

Accordingly, this laboratory could not conscientiously endorse the adoption of criteria (a), (d) or (e).

Neither can this laboratory whole-heartedly endorse criterion (c) because of the inherent arbitrariness of the term "excessive."

Criterion (b) can be endorsed, however, because the inability of armor plate to withstand the bending induced by ballistic shock is logically demonstrated by a tendency to crack under such a bending stress<sup>11</sup>.

Since such a bending stress is best applied in a sustained-rather than an instantaneous manner the use of a mushrooming projectile is to be desired. The proof projectiles used in the ballistic test by the Ordnance Research Center are considered quite satisfactory.

To illustrate that the stand of this laboratory with regard to the above criteria is well taken, and to provide preliminary data for the localization of the ideal conditions for shock testing, certain methods of evaluating the measure of correlation between the results of the metallurgical evaluations and the results of the several ballistic tests have been undertaken.

By reviewing Tables I and V, and Tables II and VI, respectively, the results of the ballistic tests made on the several samples at each of the three respective levels of severity and according to each of the five criteria recited above were compared with the results of the metallurgical evaluation. According to the measure of agreement between the metallurgical and ballistic results, a value, called its Correlation Index, was assigned to each sample, as follows:

Metallurgical Rating	Correlation Index	
	If OK Ballistically	If NG Ballistically
OK (Good)	3	0
B+ (Borderline +)	2	1
B- (Borderline -)	1	2
NG (Poor)	0	3

A tabulation of the results of such an examination is presented in Tables VII to XVI. Summaries of the average correlation indices for each combination of velocity and criterion appear in Tables XVII and XVIII, for 1" and 2" plates respectively.

From these summaries it is apparent that the best correlation (as imaged by the highest average correlation index) flows from the combination of the use of criterion b (ability to resist cracking in any degree) and a striking velocity of 1100 feet-per-second (among the velocities used), for either caliber of projectile fired against the appropriate thickness of plate.

There is, thus, good evidence that the stand of this laboratory has been well taken.

Mere correlation, however, is not considered conclusive in this examination for it can be well argued that were the striking velocities increased the correlation between the metallurgical results and the results of ballistic tests judged by other tests would improve.

In anticipation of such a contention, certain basic arguments have been advanced, above, against the use of other criteria, and the following exploration of the data will further corroborate the stand of this laboratory.

Tables VII to XVII were re-examined with special attention focused on samples having low correlation indices, i.e., values of 1 or 0.

If the ballistic result of a test showing poor correlation is OK, then the test may be assumed to be insufficiently severe; if, on the other hand, the ballistic result of such a test is NG, the test may be assumed to be too severe.

Examination of the percentage of poor correlation indices which have been "OK" ballistically under a given criterion and velocity will indicate whether or not that criterion and/or velocity is insufficiently severe, properly severe, or over-severe.

In a general way, percentages less than 50 would indicate over-severity, and values greater than 50 would indicate insufficient severity. Fifty percent would indicate the proper level of severity.

The results of such an examination appear in Table XIX and XX, for 1" and 2" plates, respectively, and have been graphically represented as functions of striking velocity and criterion in Figures 2 and 3.

These results indicate that the "excessive cracking" criterion (c) is insufficiently severe over the entire range of velocities investigated, that the "Army complete penetration" criterion (a) exhibits its irrelevance by its variable trend from under-severity to over-severity and back to proper severity, and that the "cracking in any degree" criterion (b) proceeds steadily and logically from under-severity to over-severity.

They also indicate that the combination of an irrelevant, or under-severe criterion, with, respectively, a relevant, or intermediately severe criterion, affords no more valid criterion than the latter.

Thus, coupling the irrelevant "Army complete penetration" criterion (a) with the relevant "cracking in any degree" criterion (b) affords no criterion more valid than the "cracking in any degree" criterion, nor does the combination of the under-severe "excessive cracking" criterion (c) with the intermediately severe (although irrelevant) "Army complete penetration" criterion (a) afford, in any way, a more valid criterion than the latter (a).

Further examination of these data provides a means of estimating that incident velocity for each proof projectile which will supply the optimum severity under the "cracking in any degree" criterion (b). (This will provide improved information over the introductory analysis which merely indicated the best of the tested velocities.)

By plotting the apparent trend of the severity of the "cracking in any degree" criterion (as applied both to 1" and 2" plates) from under-severity to over-severity as the incident velocity was increased, it is possible to demonstrate that the optimum velocity for incidence of both proof projectiles (57 MM T1 and 105 MM T8) lies between 1025 feet-per-second and 1050 feet-per-second, and in view of the probable extent of experimental error, the velocity may be considered identical for both. (See Figure 4.)

Since one of the 2" samples (C-65) was so completely "out of line" that it was earlier concluded that a mixup in identification had occurred<sup>12</sup>, it was considered desirable to re-plot the trend line for 2" samples with that sample eliminated. (Its inclusion in earlier calculations in no way qualitatively affected the results.) The intersection of this trend line with the 50 percent (or optimum severity) line further localizes the optimum velocity. This has been interpreted as the average of the three intersects, or 1030 feet-per-second.

On the basis of the above analysis, therefore, it is the opinion of this laboratory that the requirements for shock resistance of 1" and 2" cast armor plates, submitted under Specification AXS-492-5 should reflect the following determinations:

- a. The projectiles used should be the 57 mm. proof projectile, T1, for 1" plates and the 105 mm. proof projectile, T8, for 2" plates;
- b. The incident velocity should be  $1030 \pm 15$  feet-per-second;
- c. The criterion of success should be the ability of the armor to resist cracking in any degree.

REFERENCES

1. APG. 470.5/1476 - Wtn. 470.5/8755. 25 April 1945. See Appendix A.
2. Ordnance Research Center Report No. Ar-16241. 9 April 1945. See Appendix B.
3. Ordnance Research Center Report No. Ar-16242. 10 April 1945. See Appendix B.
4. Watertown Arsenal Laboratory Memorandum Report No. WAL 710/760. "Metallurgical Examination of 1" and 2" Thick Cast Armor Used for the Development of 57 MM. and 105 MM. Proof Projectile Shock Tests." M. Yoffa and A. Hurlach. 28 June 1945. See Appendix B.
5. Ordnance Research Center Report No. Ar-16646. 6 July 1945. See Appendix B.
6. Ordnance Research Center Report No. Ar-16647. 6 July 1945. See Appendix B.
7. APG. 470.5/76 - Wtn. 470.5/243. 23 July 1945. See Appendix A.
8. Wtn. 470.5/256 - APG. 470.5/112. 1st Indorsement. 12 September 1945. See Appendix A.
9. Watertown Arsenal Laboratory Report No. WAL 710/532. "Development of a Fracture Test to Indicate the Degree of Hardening of Armor Steels Upon Quenching." A. Hurlach. 1 August 1943.
10. Ordnance Department Bulletin. Number 21-45. 11 October 1945.
11. Watertown Arsenal Laboratory Experimental Report No. WAL 710/685. "Armor Plate Ballistic Testing." H. H. Zornig, et al. 2 August 1944.
12. See Reference 8.

TABLE I

Summary of Metallurgical Tests Conducted at Watertown Arsenal Laboratory  
on 1" Cast Armor Samples in Conjunction with Development of a  
Shock Test for Incorporation into Specification AXS-492-5

Company	Plate or Heat No.	Size of Samples As-Received	Ave. BHN*	Fibre Fracture Rating	T-Slot Charpy Data		Metallurgical Evaluation
					T-Tens. at +70°F. at -40°F.	T-Tens. at -40°F.	
American Steel Foundries	C26	12"x12"x1"	331	Fc tr	22.9	13.0	Borderline -
" " "	C22	12"x12"x1"	334	F	25.0	13.0	Borderline -
American Radiator	J43	4"x8"x1"	334	F (shrinkage)	26.5	28.0	Good
" "	J160	4"x8"x1"	359	Cbf 1/2	22.9	10.6	Poor
Ordnance Steel Mill.	B412	4"x8"x1"	341	Fc 1/4	7.9	4.1	Poor
Pratt & Letchworth	J154	4"x8"x1"	334	Fc (tr shrinkage)	34.2	15.5	Borderline +
" "	E157	4"x8"x1"	324	F (shrinkage)	24.7	18.1	Borderline -
" "	E138	4"x8"x1"	311	To 1/8	26.5	17.4	Borderline -
" "	E162	4"x8"x1"	328	F (shrinkage)	45.6	15.6	Borderline -
" "	E167	4"x8"x1"	328	F	17.4	12.1	Poor
" "	E170	4"x8"x1"	313	F	43.6	22.5	Borderline +
" "	E163	4"x8"x1"	334	Fc 1/8	23.2	13.3	Poor
" "	E186	4"x8"x1"	334	F (shrinkage)	29.5	13.0	Poor
" "	E188	4"x8"x1"	315	Cbf 1/4	28.0	10.6	Poor
Stryer Steel Company	20599	12"x12"x1"	311	Fc 1/8	30.3	26.5	Good
Scullin Steel Co.	48	12"x12"x1"	305	Fc 1/3	17.4	21.1	Poor
" "	49	12"x12"x1"	311	Fc 1/4	16.8	19.4	Poor
Symington-Gould (D)	3719	4"x8"x1"	324	Fc 1/8	26.0	15.1	Borderline -
" "	4375	4"x8"x1"	331	Fc tr	16.4	13.6	Poor
" "	4380	4"x8"x1"	301	F (shrinkage)	20.3	16.6	Borderline -
Symington-Gould (R)	3746	4"x8"x1"	299	F (shrinkage)	25.6	16.4	Borderline -
	34576	4"x8"x1"	321		35.6	26.0	Good

TABLE I (Cont'd)

\* Average of 3 cross-sectional BHN readings determined at Watertown Arsenal.

<sup>\*\*</sup>f = fibrous, Fc = fibrous matrix with spots of crystallinity. Cbf = bright crystalline patch surrounded by fibrous border. Fractions represent portion of crystalline area.  
F: tr = trace of crystallinity. Tr shrinkage = trace of shrinkage.

TABLE II

Summary of Metallurgical Tests Conducted at Watertown Arsenal Laboratory

On 2" Cast Armor Samples in Conjunction with Development of a

Shock Test for Incorporation into Specification AS-4925

Company	Plate No.	Size of Sample Ave.	BHN*	V-Notch Charpy Data			
				Fibre Fracture Rating*	% Loss. at +70°F.	% Loss. at -40°F.	Evaluation
American Steel Foundries	D277	12" x 12" x 2"	262	F	51.9	54.5	Good
	D256	12" x 12" x 2"	250	F	61.4	79.1	Good
	D257	12" x 12" x 2"	253	F	54.6	47.3	Good
	D266	12" x 12" x 2"	250	F	53.7	51.5	Good
	D261	12" x 12" x 2"	246	F	67.5	51.5	Good
Continental Foundry & Machine	663	12" x 12" x 2"	277	Fc 1/3 - D	37.1	23.5	Good
	345	12" x 12" x 2"	269	Fc 1/3 - D	28.1	17.1	Poor
	C64	12" x 12" x 2"	253	Fc 1/4 - D	38.2	28.1	Poor
	65	12" x 12" x 2"	282	Fc 1/2	33.4	23.5	Poor
Continental Foundry & Machine (W)	346	12" x 12" x 2"	269	F - D	31.2	22.5	Borderline +
	2508 (S. 178)	6" x 12" x 2"	264	Fc 1/8	32.6	35.0	Borderline +
Continental Foundry & Machine (C)	5925	6" x 12" x 2"	241	Fc 1/4	56.8	37.3	Good
	5951	6" x 12" x 2"	253	Fc tr	50.1	43.4	Good
Scullin Steel Company	545	12" x 12" x 2"	255	Fc 1/4	40.7	26.5	Poor
	550	12" x 12" x 2"	214	F	37.4	22.0	Borderline +
	650	12" x 12" x 2"	245	Cbf 1/2	66.6	55.5	Good
Symington-Gould (D)	3705	6" x 12" x 2"	264	Cbf 1/2	41.5	30.3	Borderline +
	3719	6" x 12" x 2"	237	Cbf 1/2	37.4	32.6	Borderline +
	3746	12" x 12" x 2"	246	Cbf 1/2	26.0	32.6	Borderline +
Union Steel	3734	6" x 12" x 2"	253	Fc 1/10	38.2	23.6	Good
	3740	6" x 12" x 2"	285	Fc 1/2	37.2	20.1	Poor
	3744	6" x 12" x 2"	272	Fc 1/4 (314 ft.)	47.5	22.2	Poor
				Conchooidal			

TABLE II (CONT'D)

- Average of 3 cross-sectional BHN readings determined at Watertown Arsenal.
- $\text{Fe}_f$  = fibrous,  $\text{Fe}$  = fibrous matrix with spots of crystallinity,  $\text{Co}_f$  = bright crystalline patch surrounded by fibrous border,  $\text{D}$  = dendritic,  $\text{Fe tr}$  = trace of crystallinity.  
Fractions represent portion of crystalline area.

TABLE III

Summary of Ballistic Tests of 1" Cast Armor Plates Conducted at  
 Ordnance Research Center for Development of Shock Test for  
 Incorporation into Specification AXS-1925

Company	Plate or Heat No.	57 MM Proof Projectile Velocity			1100 ft./sec.
		900 ft./sec.	1000 ft./sec.	1100 ft./sec.	
American Steel Foundries	026	PP(A) 2-1/2" cracking.	GP(A) 2-1/2" cracking.		
" "	C22	PP(A) 1" cracking.	GP(A) 4" cracking.		
American Radiator	J43	PP(A) No cracking.	PP(A) No cracking.		
" "	J160	PP(A) 1" cracking.	PP(A) 1" cracking.		
Ordnance Steel Foundry	B412	Plate broke in 3 pieces.			
Pratt & Letchworth	E154	PP(A) 2-1/4" cracking.	GP(A) 3-1/2" cracking.		
" "	E157	PP(A) 3-3/4" cracking.	PP(A) 3-3/4" cracking.		
" "	E138	PP(A) 2-3/4" cracking.	PP(A) 2-3/4" cracking.		
" "	E162	PP(A) 2" cracking.	PP(A) 2-5/8" cracking.		
" "	E167	PP(A) 1-1/2" cracking.	PP(A) 1-1/2" cracking.		
" "	E170	PP(A) 1" cracking.	PP(A) 1-1/4" cracking.		
" "	E183	PP(A) No cracking.	PP(A) 1-1/2" cracking.		
" "	E186	PP(A) " "	PP(A) 1-1/4" cracking.		
" "	E188	PP(A) " "	PP(A) 4-1/4" cracking.		
20B599		PP(A) Fine cracking.	PP(A) 2-1/2" cracking.		
Sivyer Steel Co.	48	PP(A) Fine cracking.	GP(A) 3-1/2" cracking.		
Scullin Steel Co.	49	PP(A) 2" cracking.	PP(A) 3" cracking.		
Syington-Gould (D)	J719	PP(A) No cracking.	PP(A) No cracking.		
" "	J775	PP(A) No cracking.	PP(A) No cracking.		
" "	J580	PP(A) No cracking.	PP(A) 9-1/2" cracking.		
" "	J741	PP(A) 3" cracking.	PP(A) 3" cracking.		
Syington-Gould (E)	J576	PP(A) 3-1/4" cracking.	PP(A) 3-1/4" cracking.		

TABLE IV

Summary of Ballistic Tests of 2" Cast Armor Plates Conducted at  
 Ordnance Research Center for Development of Shock Test for  
 Incorporation into Specification AAS-492-5

Company	Plate No.	105 MM Proof Projectile Velocity		
		1000+ ft./sec.	1100+ ft./sec.	1200-15 ft./sec.
American Steel Foundries	D277	PP(A) No cracking.	PP(A) No cracking.	PP(A) No cracking.
"	D256	PP(A) No cracking.	PP(A) 5-1/2" cracking.	PP(A) 5-1/2" cracking.
"	D257	PP(A) No cracking.	PP(A) No cracking.	PP(A) No cracking.
"	D266	PP(A) No cracking.	PP(A) No cracking.	PP(A) 1-1/2" cracking.
"	D261	PP(A) No cracking.	PP(A) No cracking.	PP(A) 2-1/2" cracking.
"	C63	PP(A) No cracking.	PP(A) No cracking.	PP(A) 5" cracking.
Continental Fdry & Machine	B48	CP(A) 7" cracking.	CP(A) 10" cracking.	PP(A) 3" cracking.
"	664	"	PP(A) No cracking.	PP(A) No cracking.
"	C65	"	PP(A) No cracking.	PP(A) No cracking.
"	346	"	CP(A) 6-1/2" cracking.	PP(A) 6-1/4" cracking.
Continental Fdry & Machine (W)	1367 (sq. 183)	PP(A) No cracking.	PP(A) No cracking.	CP(A) 4-1/2" cracking.
"	"	"	PP(A) No cracking.	CP(A) 4-1/2" cracking.
Continental Fdry & Machine (C)	2508 (sq. 178)	PP(A) No cracking.	PP(A) 3-1/4" cracking.	CP(A) 4-3/4" cracking.
"	5928	"	PP(A) 1-1/2" cracking.	CP(A) 1-3/4" cracking.
"	5951	"	CP(A) 5-1/2" cracking.	CP(A) 5-1/2" cracking.
Scullin Steel Co.	S48	PP(A) 2-1/2" cracking.	CP(A) 5-1/2" cracking.	PP(A) No cracking.
"	S50	PP(A) No cracking.	CP(A) 9-1/4" cracking.	CP(A) 9-1/4" cracking.
"	630	PP(A) No cracking.	CP(A) 6-1/2" cracking.	CP(A) 6-1/2" cracking.
"	681	PP(A) No cracking.	CP(A) 5-1/2" cracking.	CP(A) 5-1/2" cracking.
"	682	PP(A) No cracking.	CP(A) No cracking.	CP(A) No cracking.
Symington-Gould (D)	3705	"	PP(A) No cracking.	CP(A) 6-1/2" cracking.
"	3719	"	CP(A) 5-1/4" cracking.	PP(A) 3-1/2" cracking.
"	3746	"	PP(A) No cracking.	PP(A) No cracking.
"	4397	"	CP(A) No cracking.	CP(A) No cracking.
"	4422	PP(A) 3-1/4" cracking.	CP(A) 2-1/2" cracking.	CP(A) 2-1/2" cracking.
Union Steel	3731	PP(A) No cracking.	CP(A) 8-1/2" cracking.	CP(A) 8-1/2" cracking.
"	401A	CP(A) 8-3/4" cracking.	CP(A) 8-5/8" cracking.	CP(A) 8-5/8" cracking.

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Representation of Ballistic Results Recited in Table III.

TABLE VI

Representation of Ballistic Results Recited in Table IV

As Judged by Various Criteria

Plate No.	Company	Striking Velocity ( $\text{ft/s}^+$ ) of 105 MM Proof Projectile Tg				
		1000		1100		
		a	b	c	d	e
D277	ASF	-	-	-	-	-
D256	"	-	-	-	-	-
D257	"	-	-	-	-	-
D266	"	-	-	-	-	-
D261	"	-	-	-	-	-
C63	Continental	-	-	-	-	-
E43	"	-	-	-	-	-
C64	"	-	-	-	-	-
C65	"	-	-	-	-	-
B46	1367	-	-	-	-	-
2508	1367	-	-	-	-	-
S928	5951	-	-	-	-	-
S948	5951	-	-	-	-	-
3746	680	OK	OK	OK	OK	OK
3745	681	OK	OK	OK	OK	OK
3732	4397	OK	OK	OK	OK	OK
401A	3733	OK	OK	OK	OK	OK
Union Steel	3734	OK	OK	OK	OK	OK
Soullin	3719	OK	OK	OK	OK	OK
Sym-C (D)	3705	OK	OK	OK	OK	OK

TABLE VII

Summary of Correlations between Metallurgical Test Results and Ballistic Test Results of 1" Cast Armor Plates as Judged by "Army Complete Penetration" Criterion

TABLE VIII

Summary of Correlations between Metallurgical Test Results and Ballistic Test Results of 1" Cast Armor Plates as Judged by Cracking in Any Degree Criterion

Striking Velocity (F/st15) of 57 MM. Proof Projectile T1	1100									
	Ball.	Ret.	Dorr.	Corr.	Ball.	Ret.	Dorr.	Corr.	Ball.	Ret.
Plate or Heat No.	Res.	Res.	Ind.	Res.	Res.	Ind.	Res.	Ind.	Res.	Ind.
ASR	"	"	"	"	2	2	2	2	2	2
Amerad	"	"	"	"	3	3	3	3	3	3
OSI	"	"	"	"	NC	OK	NC	OK	NC	OK
PAL	"	"	"	"	NC	OK	NC	OK	NC	OK
Stryker	"	"	"	"	NC	OK	NC	OK	NC	OK
Scullin	"	"	"	"	NC	OK	NC	OK	NC	OK
Sym-C (D)	"	"	"	"	NC	OK	NC	OK	NC	OK
Sym-C (Z)	"	"	"	"	NC	OK	NC	OK	NC	OK
1026	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
1022	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J163	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J162	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J154	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J157	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J138	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J170	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J167	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J162	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J165	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J168	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J165	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
J168	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK
200599	OK	OK	OK	OK	NC	OK	NC	OK	NC	OK

TABLE IX

Summary of Correlations between Metallurgical Test Results and  
 Ballistic Test Results of 1" Cast Armor Plates as Judged by  
 "Incessive ( $\frac{1}{4} \text{in}$ ) Cracking" Criterion

Company	Plate or Heat No.	Striking Velocity (F/S-15) of 57 MM. Proof Projectile T1									
		900			1000			1100			
		Fall.	Ver.	Corr.	Fall.	Ver.	Corr.	Fall.	Met.	Corr.	Fall.
ASF	C26	-	-	-	OK	B-	1	OK	B-	1	1
"	C22	-	-	-	OK	B-	1	OK	B-	1	1
Amrad	J43	-	-	-	OK	B-	3	OK	OK	3	0
"	J160	-	-	-	OK	NG	0	OK	NG	1	1
OSF	3412	-	-	-	OK	NG	3	OK	NG	1	1
PAL	J154	-	-	-	OK	NG	3	OK	NG	1	1
"	J157	-	-	-	OK	B-	1	OK	NG	1	1
"	J138	-	-	-	OK	B-	1	OK	NG	1	1
"	J162	-	-	-	OK	B-	1	OK	OK	1	1
"	J167	-	-	-	OK	B-	1	OK	OK	1	1
"	J170	-	-	-	OK	B-	1	OK	OK	1	1
"	J183	OK	-	-	OK	NG	0	OK	NG	1	1
"	J186	-	-	-	OK	NG	0	OK	OK	1	1
"	J188	-	-	-	OK	NG	0	OK	OK	1	1
Silver	203599	-	-	-	OK	NG	0	OK	NG	1	1
Scoulon	"	48	OK	-	OK	NG	0	OK	NG	1	1
"	"	49	-	-	OK	NG	0	OK	OK	1	1
Syn-C (D)	3719	-	-	-	OK	NG	0	OK	OK	1	1
"	4375	-	-	-	OK	NG	0	OK	NG	1	1
"	4380	-	-	-	OK	NG	0	OK	NG	1	1
Syn-C (R)	3741	OK	-	-	OK	NG	0	OK	OK	1	1
"	34576	-	-	-	OK	NG	0	OK	OK	1	1

Table X

Summary of Correlation between Metallurgical Test Results and  
 Ballistic Test Results of 1" Cast Armor Plates as Judged by  
 "Any Complete Penetration or Cracking in Any Degree" Criterion

Striking Velocity (F/S+15) of 57 MM. Proof Projectile T1									
		900		1000		1100			
Company	Plate or Heat No.	Ball.	Met.	Ball.	Met.	Ball.	Met.	Ball.	Met.
		Res.	Ind.	Res.	Ind.	Res.	Ind.	Res.	Ind.
ASF	026	-	-	NG	3-	2	NG	3-	2
"	022	-	-	NG	3-	2	NG	3-	2
Atrad	J43	-	-	OK	OK	3	OK	3	3
	J160	-	-	OK	NG	0	NG	3	3
OSF	3412	-	-	NG	NG	3	-	-	-
P&L	3154	-	-	NG	3-	2	NG	3-	2
"	3157	-	-	NG	3-	2	NG	-	-
"	3138	-	-	NG	3-	2	NG	-	-
	3162	-	-	NG	3-	2	NG	-	-
	3167	-	-	NG	3-	2	NG	-	-
	3170	-	-	OK	NG	3+	NG	3	3
	3183	-	-	NG	NG	3	NG	3	3
	3186	-	-	NG	NG	3	NG	3	3
	3185	-	-	OK	NG	3	NG	3	3
Sivyer	203599	-	-	NG	OK	3	NG	3	3
scullin	45	-	-	NG	NG	3	NG	3	3
"	49	-	-	NG	3-	2	NG	3-	2
Sym-G (D)	3719	-	-	OK	NG	10	OK	3-	2
"	4375	-	-	OK	NG	1	NG	3-	2
"	4380	-	-	NG	NG	20	OK	-	0
Sym-G (E)	3741	-	-	NG	NG	20	NG	-	0
	34576	-	-	NG	NG	20	NG	-	0

TABLE XI

Summary of Correlation between Metallurgical Test Results and  
 Ballistic Test Results of 1" Cast Armor Plates as Judged by  
 "Partly Complete Penetration or Excessive (4½") Criterion"

Company	Plate or Heat No.	Striking Velocity (FS-15) of 57 MM. Proof Projectile Tl					
		900			1000		
		Ball. Res.	Met. Res.	Corr. Ind.	Ball. Res.	Met. Res.	Corr. Ind.
ASF	C26	-	-	-	OK	3-	1
"	C22	-	-	-	OK	3-	1
Anrad	J43	-	-	-	OK	OK	OK
"	J160	-	-	-	OK	OK	OK
OSR	3412	-	-	-	NG	3-	1
P&L	E154	-	-	-	OK	OK	OK
"	E157	-	-	-	OK	OK	OK
"	E138	-	-	-	OK	OK	OK
"	E162	-	-	-	OK	OK	OK
"	E167	-	-	-	OK	OK	OK
"	E170	-	-	-	OK	OK	OK
"	E183	-	-	-	OK	OK	OK
"	E136	-	-	-	OK	OK	OK
"	E188	-	-	-	OK	OK	OK
Slyver	2003599	-	-	-	OK	OK	OK
"	445	-	-	-	OK	OK	OK
Scullin	49	-	-	-	OK	OK	OK
Syn-G (D)	3719	-	-	-	OK	OK	OK
"	4375	-	-	-	OK	OK	OK
"	4380	-	-	-	OK	OK	OK
"	3741	-	-	-	OK	OK	OK
Syn-G (R)	34576	-	-	-	OK	OK	OK

TABLE XII

Summary of Correlations between Metallurgical Test Results and  
 Ballistic Test Results of 2" Cast Armor Plates as Judged by  
 "Army Complete Penetration" Criterion

		Striking Velocity (F/st15) of 105 MM. Proof Projectile T6											
		1000						1100					
		Ball.	Met.	Corr.	Ball.	Met.	Corr.	Ball.	Met.	Corr.	Ball.	Met.	Corr.
Plate No.	Company	Res.	Res.	Ind.	Res.	Res.	Ind.	Res.	Res.	Ind.	Res.	Res.	Ind.
D277	AST	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
D256	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
D257	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
D266	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
D261	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
C63	Continental	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
346	"	NG	-	-	NG	-	-	NG	NG	NG	NG	NG	NG
664	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
665	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
346	"	OK	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
1367	Continental (W)	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
2508	"	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
5925	Continental (C)	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
5957	"	-	-	-	-	-	-	NG	NG	NG	NG	NG	NG
346	Sculpin	-	-	-	-	-	-	OK	OK	OK	OK	OK	OK
550	"	OK	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
680	"	OK	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
681	"	OK	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
682	"	OK	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
3705	Syn-G (D)	-	-	-	OK	-	-	OK	OK	OK	OK	OK	OK
3719	"	-	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
3746	"	-	-	-	OK	-	-	OK	OK	OK	OK	OK	OK
4397	"	-	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
4422	"	-	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
3734	Union	-	-	-	OK	-	-	NG	NG	NG	NG	NG	NG
401A	"	-	-	-	NG	-	-	NG	NG	NG	NG	NG	NG

TABLE XIII.

Summary of Correlations between Metallurgical Test Results and  
 Ballistic Test Results of 2" Cast Armor Plates as Judged by  
 "Cracking in Any Degree" Criterion

Company	Plate No.	Striking Velocity (F/s <sup>15</sup> ) of 105 MM. Proof Projectile				Striking Velocity (F/s <sup>15</sup> ) of 1100 MM. Proof Projectile				Striking Velocity (F/s <sup>15</sup> ) of 1200 MM. Proof Projectile			
		Ball. Res.		Hart. Res.		Ball. Res.		Hart. Res.		Ball. Res.		Hart. Res.	
		Ball.	Hart.	Ind.	Res.	Ball.	Hart.	Ind.	Res.	Ball.	Hart.	Ind.	Res.
ASF	D277	-	-	-	-	-	-	-	-	-	-	-	-
"	D256	-	-	-	-	-	-	-	-	-	-	-	-
"	D257	-	-	-	-	-	-	-	-	-	-	-	-
"	D266	-	-	-	-	-	-	-	-	-	-	-	-
"	D267	-	-	-	-	-	-	-	-	-	-	-	-
Continental	663	-	-	-	-	-	-	-	-	-	-	-	-
"	345	NG	-	-	-	3	-	-	-	NG	-	NG	(OK)
"	664	-	-	-	-	1	-	-	-	NG	-	NG	(OK)
"	665	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	346	NG	-	-	-	1	-	-	-	NG	-	NG	(OK)
Continental (W)	1367	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	2506	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
Continental (C)	5925	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
Scullin	5951	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	348	NG	-	-	-	3	-	-	-	NG	-	NG	(OK)
"	550	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	650	OK	-	-	-	2	-	-	-	NG	-	NG	(OK)
"	651	OK	-	-	-	2	-	-	-	NG	-	NG	(OK)
"	632	OK	-	-	-	2	-	-	-	OK	-	OK	(OK)
Sym-C (D)	3705	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	3779	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	3746	-	-	-	-	-	-	-	-	OK	-	OK	(OK)
"	4397	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	4422	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
"	3734	-	-	-	-	-	-	-	-	NG	-	NG	(OK)
Union	4011	-	-	-	-	-	-	-	-	NG	-	NG	(OK)

TABLE XIV

Summary of Correlation between Metallurgical Test Results and  
 Ballistic Test Results of 2" Cast Armor Plates as Judged by  
 "Excessive ( $\frac{1}{2}$ "") Cracking" Criterion

Plate No.	Company	Striking Velocity (F/S-15) of 105 MM. Proof Projectile 18			
		1000		1100	
		Salt. Res.	Wet. Res.	Corr. Ind.	Corr. Res.
D256	ASF	OK	OK	OK	OK
D257	ASF	OK	OK	OK	OK
D266	ASF	OK	OK	OK	OK
D261	ASF	OK	OK	OK	OK
063	Continental	OK	OK	OK	OK
B43	Continental	OK	OK	OK	OK
C64	Continental	OK	OK	OK	OK
C65	Continental	OK	OK	OK	OK
B46	Continental	OK	OK	OK	OK
1367	Continental	OK	OK	OK	OK
2508	Continental	OK	OK	OK	OK
5928	Continental	OK	OK	OK	OK
5951	Continental	OK	OK	OK	OK
S45	Scullin	OK	OK	OK	OK
S50	Scullin	OK	OK	OK	OK
680	Scullin	OK	OK	OK	OK
681	Scullin	OK	OK	OK	OK
682	Scullin	OK	OK	OK	OK
3705	Sym-C (D)	OK	OK	OK	OK
3719	Sym-C (D)	OK	OK	OK	OK
3746	Sym-C (D)	OK	OK	OK	OK
4397	Sym-C (D)	OK	OK	OK	OK
4422	Sym-C (D)	OK	OK	OK	OK
4014	Sym-C (D)	OK	OK	OK	OK
	Union				

COPY

APG 470.5/1476  
 Attn: SPOTZ-F  
 Wtn. 470.5/8735(r)

1st Ind.

Hurlich/ELR/mf

CO, ASF, Watertown Arsenal, Watertown 72, Mass., 5 May 1945

To: The Director, ASF, Ord. Res. & Dev. Ctr., Aberdeen Proving Ground, Md.  
 Attn: SPOTZ-F

1. Reference basic letter, it is requested that the results of the ballistic shock tests conducted upon the 1" and 2" cast armor plates be transmitted to this arsenal in order to correlate the results of the metallurgical examination to be made at this station with the ballistic characteristics of the armor.

For the Commanding Officer:

TABLE XV

Summary of Correlations between Metallurgical Test Results and  
 Ballistic Test Results of 2" Cast Armor Plates as Judged by  
 "Army Complete Penetration or Cracking in Any Degree" Criterion

Company	Plate No.	Striking Velocity ( $T/S-15$ ) of 105 MM. Proof Projectile Tg					
		1000			1100		
		Ball. Res.	Net. Res.	Corr. Ind.	Ball. Res.	Net. Res.	Corr. Ind.
ASF	D277	-	-	-	OK	OK	OK
"	D256	-	-	-	OK	OK	OK
"	D257	-	-	-	OK	OK	OK
"	D266	-	-	-	OK	OK	OK
"	D261	-	-	-	OK	OK	OK
Continental	C63	-	-	-	OK	OK	OK
"	B48	NG	3	NG	NG	NG	NG
"	C64	-	-	OK	NG	OK	NG
"	C65	NG	B+	1	NG	NG	NG
"	B46	NG	B+	1	OK	OK	OK
Continental (W)	1367	-	-	-	NG	NG	NG
"	2506	-	-	-	OK	OK	OK
Continental (C)	5928	-	-	-	OK	OK	OK
"	5951	-	NG	-	NG	NG	NG
Scoulain	S48	-	NG	-	NG	NG	NG
"	S50	OK	B+	2	NG	OK	OK
"	680	OK	B+	2	NG	OK	OK
"	681	OK	B+	2	OK	OK	OK
Sym-G (D)	3705	-	-	-	NG	NG	NG
"	3719	-	-	-	0	0	0
"	3746	OK	-	-	OK	OK	OK
"	4397	-	NG	-	NG	NG	NG
"	4422	OK	-	-	NG	NG	NG
"	3734	-	NG	-	NG	NG	NG
Union	401A	NG	-	-	NG	NG	NG

TABLE XVI

Summary of Correlation between Metallurgical Test Results and  
Ballistic Test Results of 2" Cast Armor Plates as Judged by  
"Army Complete Penetration or Excessive (83%) Criterion"

Company	Plate No.	Striking Velocity (F/S-15) of 105 MM. Proof Projectile T8											
		1000			1100			1200			1300		
		Fall. Res.	Met. Res.	Corr. Ind.	Fall. Res.	Met. Res.	Corr. Ind.	Fall. Res.	Met. Res.	Corr. Ind.	Fall. Res.	Met. Res.	Corr. Ind.
AST	D277	-	-	-	-	-	-	OK	OK	3	OK	OK	3
"	D256	-	-	-	-	-	-	OK	OK	3	OK	OK	3
"	D257	-	-	-	-	-	-	OK	OK	3	OK	OK	3
"	D266	-	-	-	-	-	-	OK	OK	3	OK	OK	3
"	D261	-	-	-	-	-	-	OK	OK	3	OK	OK	3
Continental	063	-	-	-	-	-	-	OK	OK	3	OK	OK	3
"	344	-	-	-	-	-	-	NG	NG	3+	OK	OK	3+
"	064	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	065	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	346	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	1367	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
Continental (W)	2508	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	5926	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
Continental (C)	5927	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
Scullin	850	-	-	-	-	-	-	NG	NG	3+	OK	OK	3+
"	853	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	600	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	651	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
Sym-G (D)	3705	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	3719	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	4197	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	4122	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
"	3731	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+
Union	601	-	-	-	-	-	-	OK	OK	3+	OK	OK	3+

TABLE XVII  
Summary of Average Correlation Indices of  
1" Cast Armor Plates Fired at Various Striking Velocities  
and Evaluated by Various Criteria

<u>Criterion*</u>	<u>Striking Velocity</u>	<u>Average Corr. Index</u>
a.	900	0.33
a.	1000	1.36
a.	1100	1.69
b.	900	1.67
b.	1000	1.86
b.	1100	1.92
c.	900	0.33
c.	1000	1.05
c.	1100	1.15
d.	900	1.67
d.	1000	1.86
d.	1100	1.92
e.	900	0.33
e.	1000	1.36
e.	1100	1.69

\*See "Notes on Abbreviations."

TABLE XVIII  
Summary of Average Correlation Indices of  
2" Cast Armor Plates Fired at Various Striking Velocities  
and Evaluated by Various Criteria

<u>Criterion*</u>	<u>Striking Velocity</u>	<u>Average Corr. Index</u>
a.	1000	1.40
a.	1100	2.27
a.	1200	2.13
b.	1000	1.90
b.	1100	2.38
b.	1200	1.13
c.	1000	1.10
c.	1100	2.04
c.	1200	2.31
d.	1000	1.90
d.	1100	2.38
d.	1200	1.13
e.	1000	1.40
e.	1100	2.27
e.	1200	2.13

\*See "Notes on Abbreviations."

TABLE XIX

Summary of Percentage of Poor Correlation Indices Resulting  
from "OK" Ballistic Tests Conducted on 1" Cast Armor Plates  
at Various Velocities and Evaluated by Various Criteria

<u>Criterion*</u>	<u>Str.</u>	<u>Vel.</u>	<u>No. Poor Corr. Ind.</u>	<u>No. "OK" Ballistically</u>	<u>P.C.</u>
a		900	3	3	100.0
a		1000	14	14	100.0
a		1100	4	3	75.0
b		900	1	1	100.0
b		1000	7	4	57.1
b		1100	3	1	33.3
c		900	3	3	100.0
c		1000	17	17	100.0
c		1100	9	9	100.0
d		900	1	1	100.0
d		1000	7	4	57.1
d		1100	3	1	33.3
e		900	3	3	100.0
e		1000	14	14	100.0
e		1100	4	3	75.0

\*See "Notes on Abbreviations."

TABLE XX

Summary of Percentage of Poor Correlation Indices Resulting  
from "OK" Ballistic Tests Conducted on 2" Cast Armor Plates  
at Various Striking Velocities and Evaluated by Various Criteria

<u>Criterion*</u>	<u>Striking Velocity</u>	<u>No. Poor Corr. Ind.</u>	<u>No. "OK" Ballistically</u>	<u>P.C.</u>
a	1000	4	4	100.0
a	1100	7	3	42.9
a	1200	4	2	50.0
b	1000	3	2	66.7
b	1100	6	2	33.3
b	1200	10	1	10.0
c	1000	5	5	100.0
c	1100	7	6	85.7
c	1200	3	3	100.0
d	1000	3	2	66.7
d	1100	6	2	33.3
d	1200	10	1	10.0
e	1000	4	4	100.0
e	1100	7	3	42.9
e	1200	4	2	50.0

\*See "Notes on Abbreviations."

Notes on Abbreviations Used in Tables

Table III, IV CP(A) - Army Complete Penetration - obtained if it is possible to see light through a hole in the plate, or if any portion of the projectile in the plate is visible from the rear of the plate.

Table III, IV PP(A) - Army Partial Penetration, the result of any impact that does not fulfill the requirements for CP(A).

Table V, VI, XVII, XVIII, XIX, XX

Criterion a - "Army complete penetration" criterion.

Criterion b - "Cracking in any degree" criterion.

Criterion c - "Excessive ( $\frac{1}{4}$ " as regards 1" plates,  $\frac{1}{2}$ " as regards 2" plates) cracking" criterion.

Criterion d - Combination of criteria a and b.

Criterion e - Combination of criteria a and c.

Tables VII to XVI

Ball. Res. - Ballistic results as indicated in Tables V and VI.

Met. Res. - Metallurgical ratings given in Tables I and II.

Corr. Ind. - Correlation index, as determined in text.

GRAPHICAL REPRESENTATION OF TABLE XIX

(LETTERS REFER TO CRITERIA OF EVALUATION)

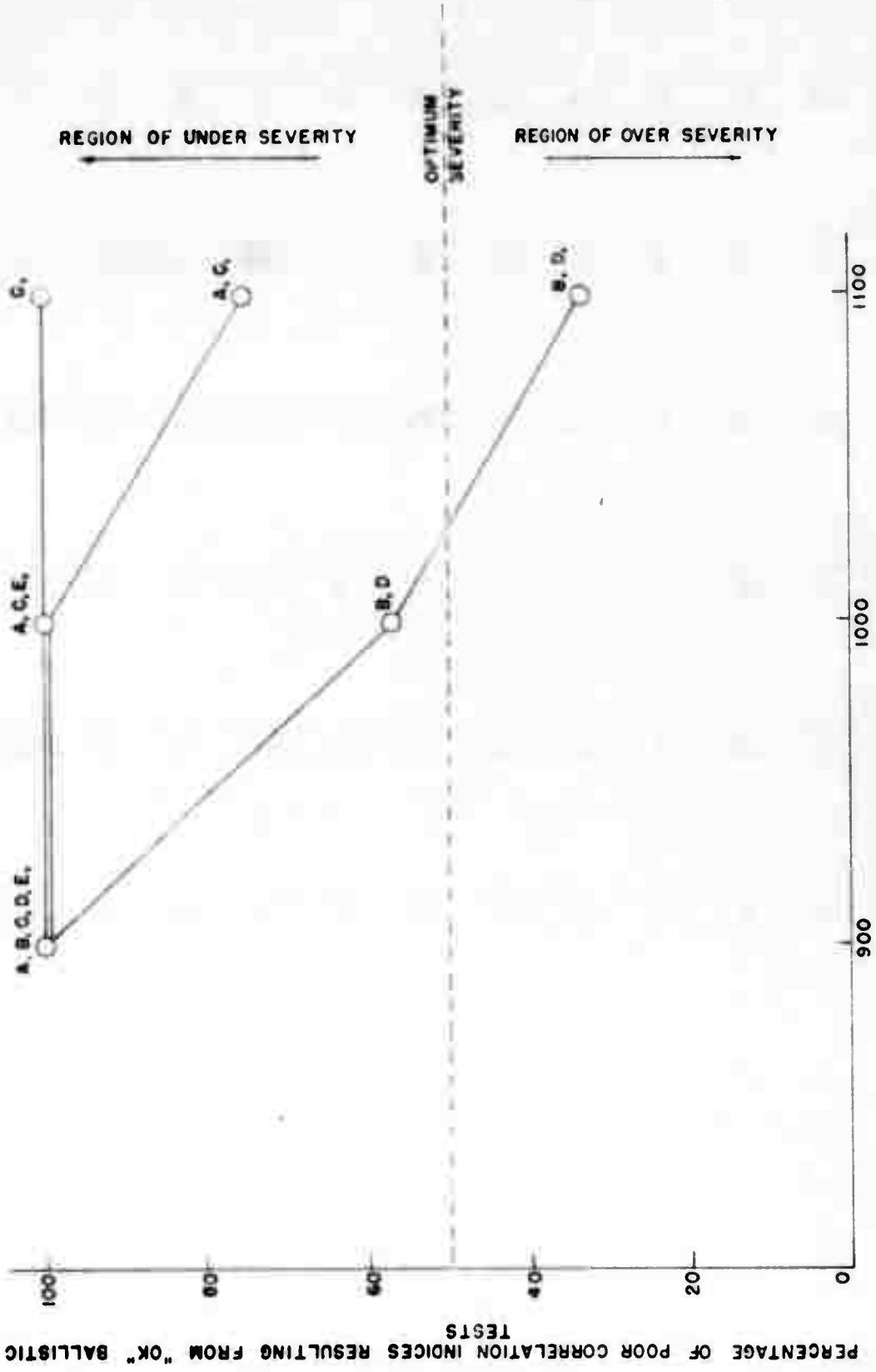


FIGURE 2

57 MM. PROOF PROJECTILE, T1, AGAINST 1" CAST ARMOR

SCHEMATIC REPRESENTATION OF EXPECTED RELATIONSHIP BETWEEN  
CHARPY IMPACT VALUE AND HARDNESS OF A GIVEN STEEL WITH  
TEMPERED MARTENSITIC MICROSTRUCTURE

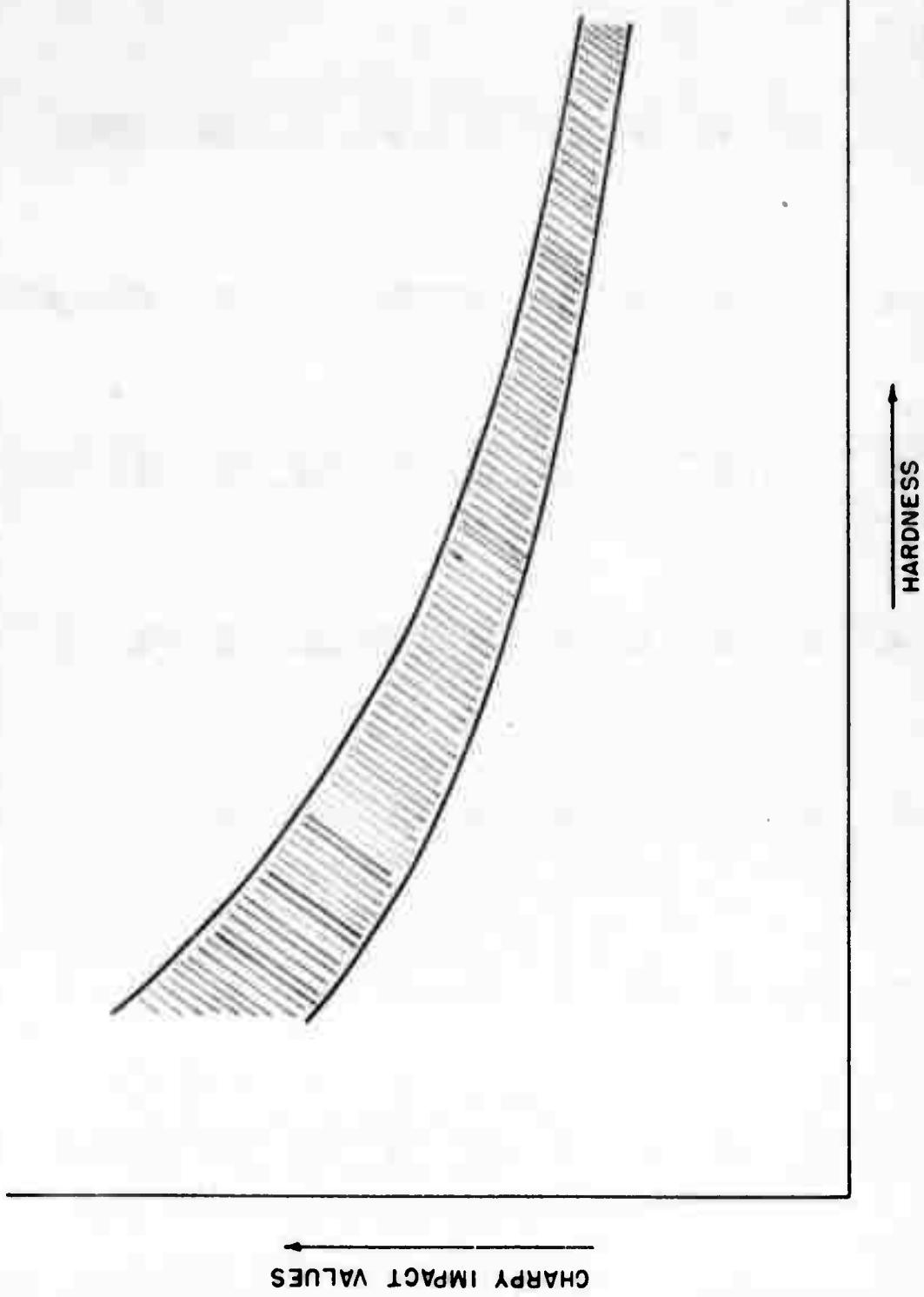
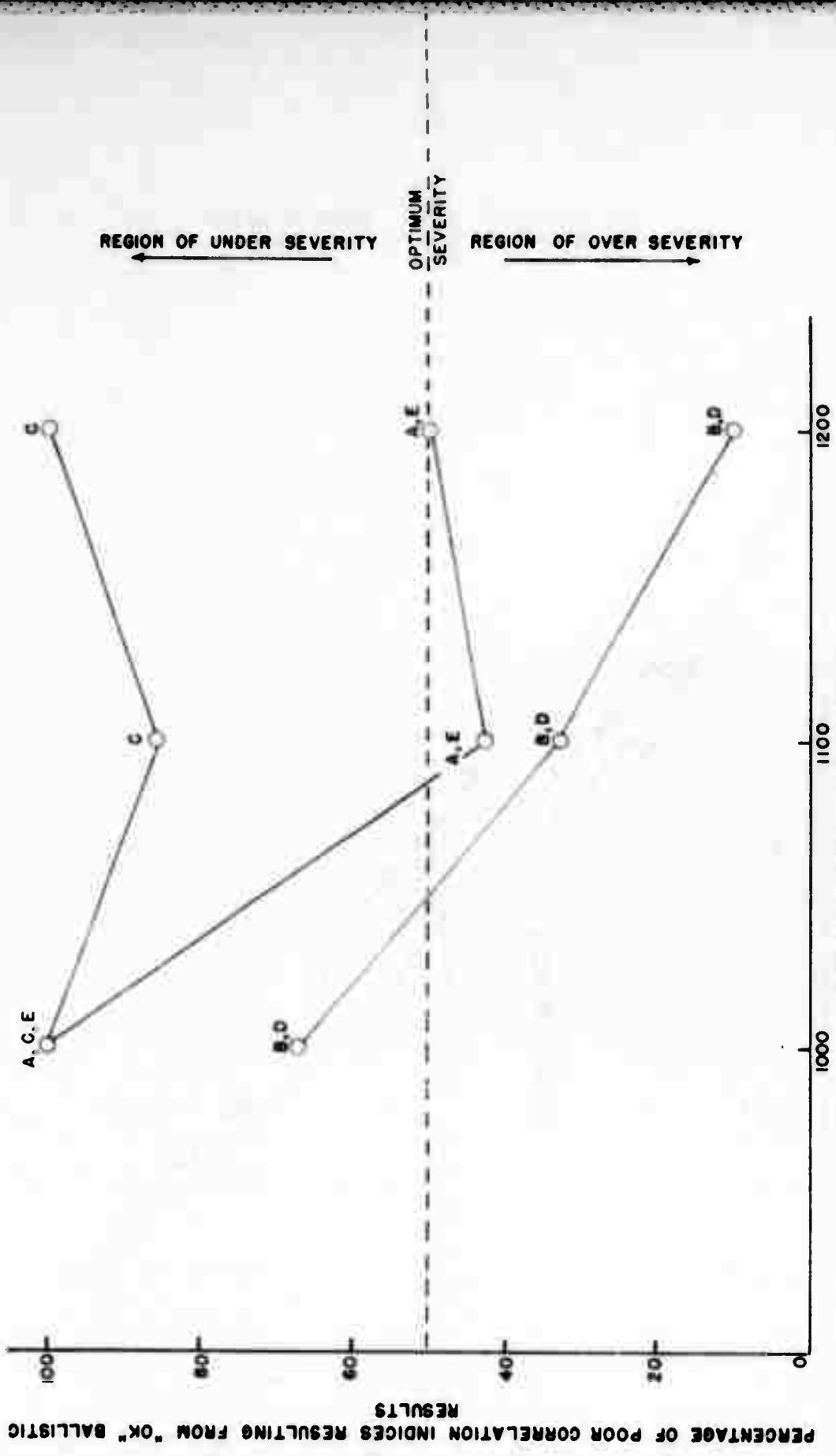


FIGURE 1

GRAPHICAL REPRESENTATION OF TABLE XXX  
 (LETTERS REFER TO CRITERIA OF EVALUATION)



105 MM. PROOF PROJECTILE, T8, AGAINST 2" CAST ARMOR

FIGURE 3

APPENDIX A

Correspondence

COPY

ARMY SERVICE FORCES  
ORDNANCE DEPARTMENT  
ABERDEEN PROVING GROUND  
MARYLAND

APG 470.5/1476  
Attn:  
SPOTZ-F

25 April 1945

SUBJECT: Development of Shock Test for 1" and 2" Cast Armor -  
Metallurgical Samples

TO: Commanding Officer  
Watertown Arsenal  
Watertown, Mass.

Attn: Laboratory - Lt. Col. N. A. Matthews

1. Fifteen samples of 2" cast plates, each approximately 6"x12" in size, and seventeen samples of 1" cast plates, each approximately 4"x8" in size are being forwarded to your station for metallurgical analysis.

2. These samples represent acceptance plates which have been shock tested with 105 mm and 57 mm proof projectiles respectively in an attempt to establish required velocities for these tests for Specification AXS-492-5.

3. It is desired that the samples be subjected to fiber fracture tests, hardness surveys, Charpy impact tests, and any other metallurgical tests deemed advisable by your office in an attempt to correlate the shock test results with the metallurgical quality of the armor. The samples may be identified as follows:

<u>2" Plates</u>			Sample No.
Company	Plate No.	Heat No.	
Continental(W)	2	1367(Sq.183)	1
" "	2	2508(Sq.178)	2
" (C)	145	5928	3
" "	147	5951	4
Symington-Gould(D)	L328	3705	5
" "	L330	3719	6
" "	L333	4380	7
" "	L334	3741	8
" "	L335	3746	9
" "	L336	4397	10
" "	L340	4422	11
Union Steel	827	373A	12
" "	833	639B	13
" "	842	401A	14
" "	844	657B	15

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APG  
 SUBJECT: Metallurgical Samples  
 TO: Watertown Arsenal

1" Plates

Company	Plate No.	Heat No.	Sample No.
American Radiator	LB352	J43	1
" "	BL355	J160	2
Ordnance Stl. Fdry.	2	B142	3
Pratt & Letchworth	Z216	E154	4
" " "	Z218	E157	5
" " "	Z244	E138	6
" " "	Z250	E162	7
" " "	Z252	E167	8
" " "	Z254	E170	9
" " "	Z259	E183	10
" " "	Z261	E186	11
" " "	Z263	E188	12
Symington-Gould(D)	L330	3719	13
" " "	L332	4375	14
" " "	L333	4380	15
" " "	L334	3741	16
" " " (R)	GB329	B4576	17

4. It will be appreciated if the results are furnished in a letter report as soon as available.

FOR THE COMMANDING GENERAL:

(S/T) G. G. EDDY  
 Col., Ord. Dept.  
 Director  
 Ordnance Res. & Dev. Cn.

2220(113 Ar3-305)

2  
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APG 470.5/1476  
Attn: SPOTZ-F  
Wtn. 470.5/8735(r)

last Ind.

Hurlich/ELR/nf

CO, ASF, Watertown Arsenal, Watertown 72, Mass., 5 May 1945

To: The Director, ASF, Ord. Res. & Dev. Ctr., Aberdeen Proving Ground, Md.  
Attn: SPOTZ-Y

1. Reference basic letter, it is requested that the results of the ballistic shock tests conducted upon the 1" and 2" cast armor plates be transmitted to this arsenal in order to correlate the results of the metallurgical examination to be made at this station with the ballistic characteristics of the armor.

For the Commanding Officer:

N. A. MATTHEWS  
Lt. Col., Ord. Dept.  
Assistant

APG 470.5/1476  
Attention: SPOTZ-F  
Wtn. 470.5/8735(r)

2nd Ind.

Oshry/nec  
Ext. 5190

ASF, Ordnance Research and Development Center, Aberdeen Proving Ground, Md.

To: Commanding Officer, Watertown Arsenal, Watertown /C, Mass.

1. In accordance with request in first indorsement, summaries of ballistic results on plates represented by subject samples are being forwarded herewith.

2. Thirty additional plates, fifteen 1" and fifteen 2" are being awaited from Gary Proof Range for ballistic tests under this same program. Samples of these plates will also be sent to Watertown Arsenal for metallurgical examination upon completion of the ballistic tests.

**FOR THE COMMANDING GENERAL:**

(S) C. J. Yaeger  
Maj. Ord. Dept.

(for) Stuart McLain  
Lt. Col., Ord. Dept.  
Acting Chief  
Arms & Ammn, Div.

Incl. = Summary of Results (2 sheets)

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SUMMARY OF RESULTS

Company	Plate No.	Heat No.	Ave. BHN	Required Vel.		Required Vel. 1000 f/s - 15 f/s	Required Vel. 1100 f/s - 15 f/s
				900 f/s + 15 f/s	1000 f/s - 15 f/s		
American Radiator	J352	J43	325			Passed	Passed
" "	13355	J160	331			Passed	Passed
Ordnance Steel Fdr'y	"	B412	321			Failed*	Passed
Pratt & Letchworth	Z216	E154	316			Passed	Passed
" "	Z218	E157	316			Passed	Passed
" "	Z244	E136	311			Passed	Passed
" "	Z250	E162	316			Passed	Passed
" "	Z252	E167	316			Passed	Passed
" "	Z254	E170	311			Passed	Passed
" "	Z259	E183	311			Passed	Passed
" "	Z261	E186	311			Passed	Passed
" "	Z263	E188	316			Passed	Passed
Symington-Gould(D)	Z330	Z719	252			Passed	Passed
" "	" "	4375	266			Passed	Passed
" "	" "	4333	4360	216		Passed	Passed
" "	" "	L774	3741	245		Passed	Failed
" "	" (R)	GB529	b4576	321		Passed	Failed

NOTES: \*This plate broke in 3 pieces; all other plates failed because of heavy complete penetrations (light visible through impact). No plate produced cracking greater than 4-1/2", except Ordnance Steel Foundry plate #2 that broke.

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SUMMARY OF RESULTS

Company	Plate No.	Heat No.	Avg. BHN	Required Vel. 1000 f/s ± 15 f/s	Required Vel. 1100 f/s ± 15 f/s	Required Vel. 1200 f/s ± 15 f/s	Passed
Continental Fibre & Mach. (C)							
"	145	5928	240				Passed
"	"	147	5951	240			Failed
"	"	(M)	2	1367	245		Passed
"	"	"	2	2503	252		Passed
Symington-Goujic (D)							
"	1328	3705	259				Passed
"	1330	3719	252				Passed
"	"	4380	261				Passed
"	"	3741	245				Passed
"	"	3746	242				Failed
"	"	4397	245				Passed
"	"	4398	267				Passed
Union Steel							
"	627	373A	264				Failed
"	633	639B	267				Failed
"	642	401A	267				Failed*
"	6414	657B	267				Failed*

Report No. AR-16241

Sheet 2 of 6

NOTE: \*Cracking in excess of 8-1/2" obtained on these plates as well as Army complete penetrations. All other plates that failed were on basis of Army complete penetrations only.

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Wtn. 470.5/8735(r)  
APG. 470.5/1476  
Attn: SPOTZ-F

3rd Ind.

/avk

ASF, Watertown Arsenal, Watertown 70, Massachusetts, 19 July 1945.

To: The Director, ASF, Ordnance Research and Development Center, Aberdeen Proving Ground, Maryland. Attn: SPOTZ-F

1. Reference paragraph 4 of basic letter, results of metallurgical examination made on 1" and 2" cast armor samples are contained in Watertown Arsenal Laboratory Memorandum Report No. WAL 710/760(r) which was forwarded to your station, reference letter file Wtn 461/905 dated 9 July 1945.

For the Commanding Officer:

N. A. MATTHEWS  
Lt. Col., Ord. Dept.  
Assistant

1 Incl w/d  
Summary of Results (2 sheets)

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ARMY SERVICE FORCES  
ORDNANCE DEPARTMENT  
ABERDEEN PROVING GROUND  
MARYLAND

APG 470.5/76  
SPOTZ-F

23 July 1945

SUBJECT: Development of Shock Test for 1" and 2" Cast Armor -  
Metallurgical Samples

TO: Commanding Officer  
Watertown Arsenal  
Watertown, Massachusetts

ATTENTION: Laboratory  
Lt. Col. N. A. Matthews

1. Fifteen samples of 2" cast plates, each approximately 12"x12" in size, and five samples of 1" cast plates, each approximately 12"x12" in size are being forwarded to your station for metallurgical analysis.

2. These samples represent acceptance plates which have been shock tested with 105 mm and 57 mm proof projectiles respectively in an attempt to establish required velocities for these tests for Specification AXS-492-5.

3. It is desired that the samples be subjected to fiber fracture tests, hardness surveys, Charpy impact tests, and any other metallurgical tests deemed advisable by your office in an attempt to correlate the shock test results with the metallurgical quality of the armor. The samples may be identified as follows:

2" Plates

<u>Company</u>	<u>Plate No.</u>	<u>Heat No.</u>	<u>Sample No.</u>
Continental Fdry. & Mach. (E. Chi.)	C8192-1 Sq C63	8192	C-63
"	B2327-2 Sq B48	2327	C-48
"	C8227-2 Sq C64	8227	C-64
"	C8260-2 Sq C65	8260	C-65
"	B2256-1 Sq B46	2256	C-46
ASF - Cast Armor Plant (Granite City)	G-7974-D-277	7526	ASF 277
"	G-7974-D-256	7447	ASF 256
"	G-7974-D-257	7454	ASF 257
"	G-7974-D-266	7481	ASF 268
"	G-7974-D-261	7468	ASF 261
Scullin Steel Co.	S-48	1-907	S-48
"	S-50	1-915	S-50
"	680	5-018	S-680
"	681	5-023	S-681
"	682	2-177	S-682

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APG

Subject: Development of Shock Test  
To: Watertown Arsenal

1" Plates

<u>Company</u>	<u>Plate No.</u>	<u>Heat No.</u>	<u>Sample No.</u>
ASF - Cast Armor Plant	C26 C22	3560 3540	C26 C22
Sivyer Steel Co.	20B599	20B599	20B599
Scullin Steel Co. "	48 49	3-333 5-020	S-48 S-49

4. It will be appreciated if the results of the metallurgical analysis are furnished in a letter report as soon as they are available.

FOR THE COMMANDING GENERAL:

G. G. EDDY  
Col Ord Dept  
Director  
Ord. Res. & Dev. Ctr.

Project No. 2220 (113 Ar3-305)

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WAR DEPARTMENT  
ABERDEEN PROVING GROUND  
MARYLAND

Rouse/ewr  
6103

APG 470.5/112  
SPOTZ-F

7 August 1945

SUBJECT: Test of 1" and 2" Thick Cast Armor

TO: Commanding Officer  
Watertown Arsenal  
Watertown 72, Massachusetts

ATTN: Laboratory, Lt. Col. N. A. Matthews

1. Reference your report WAL 710/760, "Metallurgical Examination of 1" and 2" Thick Cast Armor Used for the Development of 57 mm. and 105 mm. Proof Projectile Shock Test", page 1, under Abstracts, "Complete penetrations are not considered reliable indices of the shock resistance of armor. As presently conducted, the subject ballistic shock tests are not considered satisfactory for inclusion in Specification AXS-492-5." A further study covered by this report and the detailed results of the ballistic tests on plates covered by this report indicate that there may be a correlation between the tendency for complete penetration, and the difference in impact value at normal and subzero temperatures. This was pointed out to Mr. Sullivan from your station during his recent visit to Aberdeen Proving Ground and he was in agreement that a correlation of this type might exist.

2. On July 17, 1945, a letter request for metallurgical examination of a number of cast plates recently tested with proof projectiles was forwarded to your station. Mr. Sullivan was given detailed ballistic information on the plates represented by these samples. It is requested that the metallurgical tests on these plates be expedited and results forwarded to this station after which it is believed a sounder basis for judging the value of the complete penetration criterion in shock tests may be made.

FOR THE COMMANDING GENERAL:

Stuart McLain  
Lt. Col., Ord. Dept.  
Acting Chief, Arms &  
Ammunition Division

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Wtn. 470.5/256  
APG. 470.5/112  
Attn: SPOTZ-F

1st Ind.

Sullivan/ELR/avk

ASF, Watertown Arsenal, Watertown 72, Massachusetts, 12 September 1945.

To: The Director, ASF, Ord. Res. & Dev. Ctr., Aberdeen Proving Ground, Md.  
Attn: SPOTZ-F. Major C. J. Yaeger

1. Reference basic correspondence, during the recent visit of Mr. Sullivan of this laboratory to your station it was agreed to concentrate preliminary metallurgical study on the seven (7) two-inch thick cast plates which, based upon their resistance to cracking upon impact of the 105 mm. PP T8 projectile, represented extremes of ballistic behavior. These plates were: D-277, D-257 (both produced by American Steel Foundries), S-50 (Scullin), and C-65 (Continental) which resisted cracking; B-48, B-46 (both Continental) and S-48 (Scullin) which cracked even under a reduced test. A summary of the metallurgical findings on samples ostensibly cut from these plates and the ballistic results appears in Table I, attached.

2. The first three plates and the last three plates in that list indicate a correlation between the ballistic results, as judged on a crack/no-crack criterion, and the metallurgical characteristics,—those which were satisfactory ballistically having fibrous fractures and high impact values even at reduced temperatures and those which were unsatisfactory ballistically failing to fracture purely fibrously and having low impact values even at room temperature.

3. Sample C-65, however, which apparently resisted cracking both at 1100 f/s and 1200 f/s striking velocities possesses metallurgical characteristics which would logically be associated with inferior ballistic behavior. Thus, were one to predict ballistic behavior purely from a consideration of the metallurgical characteristics of this sample, he would anticipate poor resistance to shock. The partially crystalline fracture and the low impact values obtained on this sample ordinarily are reflected in poor ballistic behavior. The plate, however, exhibited satisfactory resistance to shock.

4. In order to delve more deeply into the problem, data obtained in the previous study of 2" cast plates (reported in WAL 710/760) were re-examined from the viewpoint of a crack/no-crack criterion of ballistic acceptability. These data are recited in Table II. They indicate a good correlation between the results of metallurgical and ballistic tests.

5. We are thus faced with a preponderance of data indicating good correlation and a single datum which glaringly indicates no correlation. It must be borne in mind that we are dealing with plates whose ballistic behavior is sharply discriminated. The plates which have been judged o.k. withstood successive impacts at 1100 feet/second and at 1200 feet/second. The plates which have been judged NG cracked under impact at 1100 feet/second and cracked again under impact at 1000 feet/second. We, thus, are not operating in a twilight zone of nebulous differences.

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Wtn. 470.5/256  
APG. 470.5/112  
Attn: SPOTZ-F

1st Ind.  
(Cont'd)

12 Sept. 1945

6. This makes the lack of correlation, even in a lone case, more disturbing than it would ordinarily be. However, it is felt that, in view of the favorable correlation apparent in the cases of ten out of the eleven samples under consideration, and in view of the consistent metallurgical results obtained on even the eleventh sample, the lack of correlation may reflect a defect in sampling the plate (wherein the sample selected may not be representative of the true quality of the plate) or may, on the other hand be due to a mixup in identification. It would thus be desirable to examine an additional sample of plate C-65 at this laboratory, and it would be appreciated if such a sample would be forwarded.

7. In general, then, there is indicated a much better correlation between results of these tests based upon a no-cracking criterion and metallurgical test results than between results based upon ballistic limits and metallurgical results. When the further modification of the weight of the test projectile suggested during the visit of Mr. Sullivan has been made, it is felt that a much better correlation will appear.

8. The complete results of the metallurgical examination of the subject armor will be forwarded by memorandum report.

For the Commanding Officer:

N. A. MATTHEWS  
Lt. Col., Ord. Dept.  
Assistant

2 Incls  
Tables I & II

3  
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TABLE I  
2" Cast Homogeneous Plates

Reference - AR-16646

105 mm. PP T8

Company	Plate No.	Ave. BHN Co. Wtn.	Fracture	Charpy +70°F. -10°F.	Ballistic (No Crack Criterion)
ASPF-CAP	D-277	251 262	F	51.9	54.5
ASPF-CAP	D-257	245 253	F	54.6	47.0
Scullin	S-50	232 214	F	63.6	55.5
Continental	C-65	266 282	PC 1/2	33.4	21.0
Continental	B-48	266 269	PC 1/3 D	29.1	17.1
Continental	B-46	255 269	FD	31.2	29.5
Scullin	S-48	234 255	PC 1/2	37.4	22.0

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Appendix A - Page 12

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C. D. Reg. No.  
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ARMOR BRANCH  
ORDNANCE RESEARCH AND DEVELOPMENT CENTER  
ABERDEEN PROVING GROUND, MARYLAND

SUBJECT: Development of a Shock Test for  
1" and 2" Cast Armor.

Report No.: Ar-16241  
Date of Test: 9 April 1945  
Sheet 1 of 6  
Related P.R. No.: 3965  
Project No.: 2220(113-Ar3-305)  
References: OOM 470.5/APG(10 Feb  
45)R; SPOME-EE  
APG 470.5/1161

OBJECT: To Obtain Shock Test Data with  
the 105 mm. Proof Projectile on a  
Total of Fifteen 2" Cast Acceptance  
Plates Received from Erie Proving  
Ground.

COMMENTS:

1. Fifteen 2" cast plates, received from Erie Proving Ground after passing acceptance tests for penetration, were shock tested with 105 mm. proof projectiles in order to obtain data to establish a required velocity for Specification AXS-492.

2. In this test, one round was placed against the center of the plate at a required velocity of 1100 f/s. If the plate withstood the impact without excessive cracking, a second round was fired at a velocity 100 f/s higher. If the plate cracked as a result of the first impact, the second round was fired at a velocity 100 f/s lower. Failure was considered to have occurred when cracking extended greater than 8-1/2" and/or Army complete penetration was obtained (light visible through impact).

3. A summary of this test is given on sheet 2. A list of test facilities is given on sheet 3. The detailed results are on sheets 4 through 6.

4. This is the first report on test data on this project. Testing will continue.

APPROVED:

G. G. EDDY  
Col., Ord Dept  
Director

BY:

(s) H. J. Rouge Sr. Eng.  
for JOHN W. CAVE  
Col., Ord Dept  
Chief, Arms & Ammunition  
Division

(s,t) G. H. OSHERY  
Metallurgist, P-4  
Proof Director

Distribution of this report:

Commanding General, Office, Chief  
of Ordnance-Detroit, Attention: SPOME-EE

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SUMMARY OF RESULTS

Company	Plate No.	Heat No.	Ave. BHN	Required Vol. 1000 f/s + 15 f/s	Required Vol. 1100 f/s + 15 f/s	Required Vol. 1200 f/s + 15 f/s
Continental Pdry. & Mach. (C)	145	5928	240	Passed	Passed	Passed
" " "	147	5951	240	Passed	Passed	Passed
" " "	" (W)	2	1367	245	Passed	Passed
" " "	" "	2	2508	252	Passed	Passed
Symington-Gould (D)	1328	3705	259	Passed	Passed	Passed
" " "	1330	3719	252	Passed	Passed	Passed
" " "	1333	4380	261	Passed	Passed	Passed
" " "	1334	3741	245	Passed	Passed	Passed
" " "	1335	3746	242	Passed	Passed	Passed
" " "	1336	4397	245	Passed	Passed	Passed
" " "	1340	4422	267	Passed	Passed	Passed
Union Steel	827	373A	264	Passed	Passed	Passed
" " "	833	639B	267	Passed	Passed	Passed
" " "	842	401A	267	Failed*	Failed*	Failed*
" " "	844	657B	267	Passed	Passed	Passed

NOTE: \*Cracking in excess of 8-1/2" obtained on these plates as well as Army complete penetrations. Other plates that failed were on basis of Army complete penetrations only.

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Report No.: Ar-16241  
Sheet 3 of 6

Test Facilities:

a. Guns Used:

Howitzer, Field, 105 mm., M2A1, No. 347, Mf'd. by the Vilter M'fg. Co.

b. Projectiles Used:

Projectile, Proof, T8, 105 mm., Lot FA-E-75.

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 9 April 1945  
ARMOR TEST REPORT NO. Ar-16241  
SHEET 4 OF 6  
RELATED F.R. NO. AF 3965

RD. No.	PROJECTILE	S	AVG. THICK.	REQ. VEL.	ACT. S.V.	PP CP PTP	PLATE NO.	HEAT NO.	THICKNESS & TYPE
							RESULTS - ARMOR AND PROJECTILE		
1	Symington-Gould-(D); Plate No. L333-1;	0°	1.98	1090	1109	PP(A)	Heat 4380; BHN 261		MB - no cracking; Mushroomed & intact
	105mm PP T8								
2	"	"	"	1199	1202	CP(A)	5-1/4", 5-1/4", 4-3/8" cracks; Mushroomed & intact		
	Symington-Gould(D); Plate No. 330-1;								
1	105mm PP T8	0°	2.00	1100	1084	PP(A)	Heat 3719; BHN 252 MB - no cracking; Mushroomed & intact		
	"								
2	"	"	2.00	1200	1198	PP(A)	MB - 3½", 3-3/8" crack; Mushroomed & intact		
	Symington-Gould-(D); Plate No. L340-1;								
1	105mm PP T8	0°	2.02	1110	1117	CP(A)	Heat 4422; BHN 267 9½", 7½", 7½" to prev. impact; Mushroomed & intact		
	"								
2	"	"	2.00	1000	989	PP(A)	3-1/4", 2½" cracks; prev. ck. extended 16"; Mushroomed & intact		
	Continental Fdry. & Mach. Co.(W); Plate No. 2;								
1	105mm PP T8	0°	2.10	1150	1149	PP(A)	Heat 2508 Sq 178; BHN 252 MB - no cracking; Mushroomed & intact		
	"								
2	"	"	2.10	1250	1259	CP(A)	4½", 3-5/8" cracks; Mushroomed & intact		
	Symington-Gould-(D); Plate No. L335-1;								
1	105mm PP T8	1.98	1090	1095	CP(A)	Heat 3746; BHN 242 5-1/4", 5", 3-3/4" cracks; Mushroomed & intact			
	"								
2	"	1.95	975	995	PP(A)	MB - No cracking; Mushroomed & intact			
	Union Steel; Plate No. 842; Heat 401A;								
1	105mm PPT8	0°	1.86	1030	1031	CP(A)	BHN 267 8-5/8", 8½", 6½" cracks; Mushroomed & intact		
	"								
2	"	"	1.85	925	910	CP(A)	8-3/4", 7½", 5-3/4" cracks; Mushroomed & intact		

CP - Complete Penetration

PP - Partial Penetration

CIP - Core in plate

PUM S - Punching started

BS - Back spall

FS - Face spall

SC - Star cracking

DC - Disregard

CR - Cratering

PF - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

FPTP - Failed to pass thru plate.

ND - Nose destroyed

BD - Base destroyed

NI - Nose intact

BI - Base intact

PC - Partial cratering

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 9 April 1945  
 ARMOR TEST REPORT NO. Ar-16241  
 SHEET 5 OF 6  
 RELATED F.R. NO. AF 3965

PLATE NO.

HEAT NO.

THICKNESS &amp; TYPE

RD NO.	PROJECTILE	Q SFC	Avg. VEL.	REQ. VEL.	ACT. S.V.	PP CP PTP	RESULTS - ARMOR AND PROJECTILE
1	Symington-Gould-(D); Plate 105mm PP TG	0°	1.96	1090	1095	PP(A)	L-336-1; Heat 4397; BHN 245 LB - no cracking; Mushroomed & intact
2	"	"	1.97	1160	1164	PP(A)	LB - no cracking; Mushroomed & intact
1	Union Steel; Plate 833; Heat 373A; BHN 264						
1	105mm PP TG	0°	1.96	1080	1094	CP(A)	4½", 4½", 4"; Mushroomed & intact
2	"	"	2.01	1005	989	PP(A)	MB - no cracking; Mushroomed & intact
1	Continental Fdry. & Mach.(C); Plate No. 145; Heat 5928; BHN 245						
1	105mm PP TG	0°	2.03	1115	1112	PP(A)	MB - no cracking; Mushroomed & intact
2	"	"	2.03	1215	1226	PP(A)	LB - 3/4" crack; Mushroomed & intact
1	Symington-Gould-(D); Plate L-334-1; Heat 3741; BHN 245						
1	105mm PP TG	0°	2.01	1105	1106	PP(A)	4", 2-1/4", 3-3/4" cracks, Mushroomed & intact
2	"	"	1.99	1195	1205	CP(A)	6-3/4", 6", 5", 5-3/4"; Mushroomed & intact
1	Union Steel; Plate No. 833; Heat 639B; BHN 267						
1	105mm PP TG	0°	2.05	1125	1124	CP(A)	4-3/4", 4-1/4", 5", 4-3/4" cracks; Mushroomed & intact
2	"	"	2.00	1000	991	PP(A)	2½", 2-3/4", cracks; Mushroomed & intact
1	Continental Fdry. and Mach. Co.(W); Plate No. 2; Heat L367 Sq. 183; BHN 245						
1	105mm PP TG	0°	2.16	1180	1200	PP(A)	MB - no cracking; Mushroomed & intact
2	"	"	2.15	1275	1283	PP(A)	Cracks off bulge 5-1/4", 5-1/4"; Mushroomed & intact

CP - Complete Penetration

PP - Partial Penetration

CIP - Core in plate

PUS S - Punching started

BS - Back spall

FS - Face spall

SC - Star cracking

D - Disregard

C - Cratering

P - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

IPTP - Failed to pass through plate

ND - Nose destroyed

BD - Base destroyed

NI - Nose intact

BI - Base intact

PC - Partial cratering

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 9 April 1945  
ARMOR TEST REPORT NO. Ar-16241  
SHEET 6 OF 6  
RELATED F.R. NO. AF 3965

RD. NO.	PROJECTILE	HEAT NO.			THICKNESS & TYPE		
		IN. O.S.	CM. F.H.	REQ. W.L.	ACT. S.V.	PP CP PTP	RESULTS - ARMOR AND PROJECTILE
1	Union Steel; Plate No. 844; Heat 657B; BHN 267						
1	105mm PP T8 0°	1.98	1090	1091	CP(A)	8-3/4", 8", 3" cracks; Mushroomed & intact	
2	" "	1.87	935	919	PP(A)	5-1/4", 2"; Mushroomed & intact	
	Symington-Gould(D); Plate 328-1; Heat 3705; BHN 259						
1	105mm PP T8 0°	1.93	1065	1078	PP(A)	LB - no cracking; Mushroomed & intact	
2	" "	1.91	1155	1159	CP(A)	6", 5-1/4", 6" cracking; Mushroomed & intact	
	Continental Fdry. & Mach. Co.-(D); Plate No. SC-147; Heat 5951; BHN 240						
1	105mm PP T8 0°	2.11	1155	1156	PP(A)	LB - 1-1/2" crack; Mushroomed & intact	
2	" "	2.16	1280	1271	CP(A)	4-3/4", 4" cracks; Mushroomed & intact	

CP - Complete Penetration  
PP - Partial Penetration  
PIP - Projectile in plate  
PIP S - Punching started  
BS - Back spall  
FS - Face spall  
SC - Star cracking  
PC - Piercing  
P - Petaling on face

PTP - Passed through plate  
PIP - Projectile in plate  
NPTP - Failed to pass through plate.  
ND - Nose destroyed  
BD - Base destroyed  
NI - Nose intact  
BI - Base intact  
PC - Partial cratering

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ARMOR BRANCH  
ORDNANCE RESEARCH AND DEVELOPMENT CENTER  
ABERDEEN PROVING GROUND, MARYLAND

SUBJECT: Development of a Shock Test  
for 1" and 2" Cast Armor.

Report No.: Ar-16242  
Date of Test: 10 April 1945  
Sheet 1 of 6  
Related F.R. No.: AF 3967  
Project No.: 2220(113 Ar3-305)  
References: OOM 470.5/APG(10 Feb  
45)R; SPOME-EE  
APG 470.5/1161

OBJECT: To Obtain Shock Test Data with  
the 57mm. Proof Projectile on  
a Total of Seventeen 1" Cast  
Plates received from Erie Proving  
Ground

COMMENTS:

1. Seventeen 1" cast plates, received from Erie Proving Ground after passing acceptance tests for penetration, were shock tested with the 57 mm. proof projectile in order to obtain data to establish a required velocity for Spec. ~~AMM-292~~.

2. In this test, one round was placed against the center of the plate at a required velocity of 1000 f/s. If the plate withstood the impact without cracking excessively, a second round was fired at a velocity 100 f/s higher. If the plate cracked excessively on the first impact, the second round was fired at a velocity 100 f/s lower. Failure was considered to have occurred when cracking extended greater than 4-1/2" (two calibers) and/or an Army complete penetration was obtained (light visible through impact).

3. A summary of this test is given on sheet 2. A list of test facilities is given on sheet 3. The detailed results are on sheets 4 through 6.

4. This is the second report of test data on this project. Testing will continue.

APPROVED:

BY:

G. G. EDDY  
Col., Ord. Dept.  
Director

(s) H. J. Rouse Sr. Eng  
for JOHN W. CAVE (s/t) G. H. OSHERY  
Col., Ord. Dept. Metallurgist, P-4  
Chief, Arms & Ammn. Div. Proof Director

Distribution of this report:

Commanding General, Office, Chief of  
Ordnance-Detroit, Attention: SPOME-EE

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SUMMARY OF RESULTS

Company	Plate No.	Ave. BHN	Required Vol.		Required Vol. 1100 f/s ± 15 f/s
			900 f/s ± 15 f/s	1000 f/s ± 15 f/s	
American Radiator	L3352	J43	325	Passed	Passed
" "	L3355	J160	331	Passed	Passed
Ordnance Steel Fdry.	2	B412	321	Failed*	Passed
Pratt & Letchworth	2216	K154	316	Passed	Failed
" "	2218	K157	316	Passed	Failed
" "	2244	K138	311	Passed	Failed
" "	2250	K162	316	Passed	Failed
" "	2252	K167	316	Passed	Failed
" "	2254	K170	311	Passed	Failed
" "	2259	M83	311	Passed	Failed
" "	2261	M86	311	Passed	Passed
" "	2263	M88	316	Passed	Failed
Symington-Gould(D)	L330	J719	252	Passed	Failed
" "	L332	K375	265	Passed	Passed
" "	L333	4380	216	Passed	Failed
" "	L334	J741	245	Passed	Failed
" "	03329	B4576	321	Passed	Failed

NOTES: \*This plate broke in 3 pieces; all other plates failed because of Army complete penetrations (light visible through impact). No plate produced cracking greater than 4-1/2", except Ordnance Steel Foundry plate #2 that broke.

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 9 April 1945  
ARMOR TEST RPT. NO. Ar-16242  
SHEET 4 OF 6  
RELATED F.R. NO. AF-3967

RD. NO.	PLATE NO.	PROJECTILE	HEAT NO.			THICKNESS & TYPE			RESULTS - ARMOR AND PROJECTILE
			D	H	V	REQ. VEL.	ACT. S.V.	PP CP PTP	
1	Pratt & Letchworth; Lot Z259-1; Heat E183; BHM 311	57mm PP T1	0°	.98	984	995	CP(A)	4", 3½", 3" cracks; Mushroomed & Intact	
2	" " 1.00 900 902 PP(A) MB - no cracking; Mushroomed & Intact								
1	Symington-Gould(D); Plate I330A; Heat J719; BHM 252	57mm PP T1	0°	.99	992	1001	PP(A)	LB - no cracking; Mushroomed & Intact	
2	" " 1.01 1108 1106 CP(A) 2½", 2½" cracks; Mushroomed & Intact								
1	Pratt & Letchworth; Lot Z250-1; Heat E162; BHM 316	57mm PP T1	0°	1.01	1008	1002	PP(A)	1½", 1-7/8", 2" cracks; Mushroomed & Intact	
2	" " 1.01 1108 1106 CP(A) 2-3/4", 2½", 1-5/8" cracks; Mushroomed & Intact								
1	American Radiator Plate LB355; Heat J160; BHM 331	57mm PP T1	0°	1.03	1024	1026	PP(A)	LB - no cracking; Mushroomed & Intact	
2	" " 1.01 1108 1110 PP(A) 1-1/4", 1", ½" cracks; Mushroomed & Intact								
1	Pratt & Letchworth; Lot Z261-1; Heat E186; BHM 311	57mm PP T1	0°	1.05	1064	1082	PP(A)	1½", 1-3/8" cracks; Mushroomed & Intact	
2	" " 1.05 1164 1146 PP(A) 1-1/4", 1" cracks; Mushroomed & Intact								
1	Pratt & Letchworth; Lot Z254-1; Heat E170; BHM 311	57mm PP T1	0°	1.00	1000	995	PP(A)	PP(A); 1½", 1-1/4", 1" cracks;	
2	" " 1.00 1100 1114 CP(A) Mushroomed & Intact CP(A); 3-3/4", 3-1/8"; 2-1/4" cracks; Mushroomed & Intact								

CP - Complete Penetration  
PP - Partial Penetration  
CIP - Core in plate  
PUN S - Punching started  
BS - Back spall  
FS - Face spall  
SC - Star cracking  
D - Disregard  
C - Cratering  
- Pitting on face

PIP - Passed through plate  
PIP - Projectile in plate  
NTP - Failed to pass through plate  
ND - Nose destroyed  
BD - Base destroyed  
NI - Nose intact  
BI - Base intact  
PC - Partial cratering

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Report No. 1 Ar-16242  
Sheet 3 of 6

Test Facilities:

a. Guns Used:

Gun, A.T., 57 mm, M1, No. 726, Mfd. by A.T.F.  
Tube, A.T., 57 mm, M1, No. 1019, Mfd by A.T.F.

b. Projectiles Used:

Projectile, Proof, T1, 57 mm. AK 3-1

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 10 April 1945  
ARMOR TEST REPORT NO. Ar-16242  
SHEET 5 OF 6  
RELATED F.R. NO. AF 3967

RD. NO.	PROJECTILE	C O E R	AVG. THICK	REQ. VEL.	ACT. S.V.	PP CP PIP	HEAT NO.	THICKNESS & TYPE
							RESULTS - ARMOR AND PROJECTILE	
	Pratt & Letchworth; Lot Z252-1; Heat E167; BHM 316							
1	57mm PP T1	0°	.99	992	1015	PP(A)	2-5/8", 2-1/4", 2" cracks; Mushroomed and Intact	
2	"	"	1.00	1100	1098	CP(A)	3-3/4", 3-1/2", 2-1/2", 2-1/4" cracks; Mushroomed and intact	
	Pratt & Letchworth; Lot Z218-1; Heat E157; BHM 316							
1	57mm PP T1	0°	1.02	1016	991	PP(A)	3-3/4", 2-3/8", 2-1/4" cracks; Mushroomed and Intact	
2	"	"	1.02	1116	1115	CP(A)	4-1/4", 4", 3-1/4", 2-1/2" cracks; Mushroomed and intact	
	Pratt & Letchworth; Lot Z216-1; Heat E154; BHM 316							
1	57mm PP T1	0°	1.01	1008	993	PP(A)	2-1/4", 2" cracks; Mushroomed and intact	
2	"	"	1.02	1116	1111	CP(A)	3-1/2", 2-7/8", 2-1/2"	
	Symington-Gould (D) Plate L333A; Heat 4380; BHM 216							
1	57mm PP T1	0°	.97	976	978	PP(A)	ND; No cracking	
2	"	"	.96	1068	1064	CP(A)	4-1/2", 3-3/4", 3-1/4" cracks; Mushroomed and intact	
	Pratt & Letchworth; Lot Z244-1; Heat E138; BHM 311							
1	57mm PP T1	0°	1.02	1016	1018	PP(A)	2-3/4", 2-1/2", 2-1/2" cracks; Mushroomed and intact	
2	"	"	1.02	1116	1095	CP(A)	3-1/2", 3-1/4", 3" cracks; Mushroomed and intact	
	Ordnance Steel Foundry; Plate 2; Heat B412; BHM 321							
1	57mm PP T1	0°	1.00	1000	987		Plate broke in three pieces.	

CP - Complete Penetration  
PP - Partial Penetration  
CIP - Core in Plate  
PUS - Punching started  
BS - Back spall  
FS - Face spall  
SC - Star cracking  
D - Disregard  
C - Cratering  
P - Petaling on face

PIP - Passed through plate  
PIP - Projectile in plate  
NTP - Failed to pass through plate  
ND - Nose destroyed  
BD - Base destroyed  
NI - Nose intact  
BI - Base intact  
PC - Partial cratering

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 10 April 1945  
ARMOR TEST REPORT NO. AF-16242  
SHEET 6 OF 6  
RELATED P.R. NO. AF 3967

RD. NO.	PROJECTILE	HEAT NO.			THICKNESS & TYPE			RESULTS - ARMOR AND PROJECTILE
		$\frac{O}{M}$	$\frac{S}{M}$	REQ. VUL.	AOT. S.V.	PP CP PIP		
1	Pratt & Letchworth; Lot 2263-1; Heat B155; BHM 316							
1	57mm PP T1	0°	.99	992	991	PP(A)	2-1/4", 2-1/4" cracks; Mushroomed and intact	
2	"	"	1.00	1100	1119	CP(A)	4", 4-1/4", 3-1/4" cracks; Mushroomed and intact	
	Symington-Gould; Plate L332A; Heat 4375; BHM 266							
1	57mm PP T1	0°	.97	976	985	PP(A)	LB; No cracking	
2	"	"	.97	1076	1071	PP(A)	LB; No cracking	
	Symington-Gould; Plate 334; Heat 3741; BHM 245							
1	57mm PP T1	0°	.98	984	975	CP(A)	3", 2-7/8", 1-3/4" cracks; Mushroomed and intact	
2	"	"	.98	554	Est. 554	PP(A) 554(Lost)	2-3/4", 1-1/4", 1" cracks; Mushroomed and intact	
	American Radiator; Plate No. LB352; Heat J43; BHM 325							
1	57mm PP T1	0°	1.10	1050	1095	PP(A)	ND; No cracking	
2	"	"	1.11	1158	1151	PP(A)	LB; "	
	Symington-Gould (R); Plate GB 329; Heat 4576; BHM 321							
1	57mm PP T1	0°	1.04	1032	1035	PP(A)	ND; 3/4" cracks; Mushroomed and intact	
2	"	"	1.05	1140	1163	CP(A)	3-1/4", 3", 2-1/8" cracks; Mushroomed and intact	

CP - Complete Penetration  
PP - Partial Penetration  
OIP - Core in plate  
PSS - Punching started  
BS - Back spall  
FS - Face spall  
SC - Star cracking  
D - Disregard  
C - Cratering  
F - Pitting on face

PIP - Passed through plate  
PIP - Projectile in plate  
NPIP - Failed to pass through plate  
ND - Nose destroyed  
NI - Nose intact  
BI - Base intact  
PC - Partial cratering

WATERTOWN ARSENAL LABORATORY

MEMORANDUM REPORT NO. VAL 710/760

First Partial Report on Problem B-4.78

26 June 1945

Metallurgical Examination of 1" and 2" Thick

Cast Armor Used for the Development of

57 MM and 105 MM Proof Projectile Shock Tests

Abstract

Except for a few cases, the ballistic performance of 1" and 2" thick cast armor shock tested at velocities of 1000 and 1100 ft./sec. with 57 mm. and 105 mm. proof projectiles respectively does not correlate with the shock properties of the armor as revealed by metallurgical tests. There is evidence that low hardness is the factor responsible for the failure of 1" thick plates during the shock test. In general, the ballistic failures resulted from complete penetrations (Army criterion) rather than from breakage or excessive cracking. Complete penetrations are not considered reliable indices of the shock resistance of armor. As presently conducted, the subject ballistic shock tests are not considered satisfactory for inclusion in Specification AIB-492-5.

1. At the request of the Ordnance Research Center, Aberdeen<sup>1</sup>, a metallurgical examination of seventeen 1" and eleven 2" thick cast armor plates has been completed. These plates had been shock tested with 57 mm. and 105 mm. proof projectiles respectively in an attempt to establish required velocities for these tests for incorporation in Specification AIB-492-5.
2. Metallurgical examination and an evaluation of the results of the ballistic tests lead to the following observations and conclusions.

- a. The 57 mm. proof projectile shock tests at velocities of 1000 ft./sec. and 1100 ft./sec. are not considered satisfactory as criteria of the shock resistance of 1" thick cast armor since metallurgical tests show, in general, no difference in shock properties between plates which

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1. AFM. 470.5/1476 - Wm. 470.5/5735 dated 25 April 1945.

passed and plates which failed the test. Furthermore, plates generally failed the test because of complete penetrations (Army criterion) rather than cracking or breaking. Complete penetrations are not satisfactory indices of poor shock resistance.

b. The ballistic behavior of 2" thick cast armor shock tested at a velocity of 1000 ft./sec. with 105 mm. proof projectiles does correlate somewhat more satisfactorily with the shock properties as revealed by metallurgical tests. Complete penetrations (Army criterion) occurred, however, in some of the failing plates. The philosophy of failing plates as the result of complete penetrations during shock testing is open to severe criticism.

3. The metallurgical examination included the following tests:

- a. Fibre fracture test.
- b. Cross-sectional Brinell hardness survey.
- c. V-notch Charpy impact tests.

The 6"x12"x2" and 4"x8"x1" sections were notched by flame cutting in from the middle of the two longer sides and were fractured under the impact of a steam forge hammer. One-half inch thick sections cut from the middle of one of the fractured halves were surface ground. Brinell hardness surveys were made on the cross-sectional surfaces, after which two V-notch Charpy impact specimens were machined from each section, from positions halfway between the surface and the center in the case of the 1" thick plates and from near the center of the 2" thick plates. One impact specimen from each plate was tested at +70°F. and the other at -40°F.

4. The details regarding the ballistic performance, hardness, fibre fracture rating, and notched bar impact values of the 1" and 2" thick plates are tabulated in Tables I and II respectively.

5. According to the ballistic data forwarded to this arsenal with the 2nd indorsement to the basic letter<sup>1</sup>, all but a very few of the plates which failed the shock test at the various velocities failed because of complete penetrations (Army criterion). The fact that failure occurred through complete penetration rather than as a result of breakage or cracking of the test plates casts immediate doubt upon the success of 57 mm. and 105 mm. proof projectiles employed to shock test 1" and 2" thick cast armor respectively. A complete penetration cannot in itself be considered an adequate proof of poor shock properties. The one 1" thick plate, Ordnance Steel Foundry plate 2, heat B142, which did break up under the impact of a 57 mm. proof projectile was found to possess extremely poor impact properties, having an impact energy of 7.9 ft.lbs. at +70°F. and 4.1 ft.lbs. at -40°F. Likewise, two 2" thick plates which cracked in excess of 8 $\frac{1}{2}$ ", Symington-Gould, heat

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1. See reference on preceding page.

4422 and Union Steel, heat 401A, possessed relatively poor low temperature impact properties. Except for these three isolated cases, however, no correlation can be established between the ballistic performance and the shock properties as determined by metallurgical tests.

6. In order to more clearly demonstrate the lack of correlation between the results of the ballistic and the metallurgical shock tests, the data were rearranged as shown in Tables III and IV. The hardnesses, impact properties, and fibre fracture ratings of the plates which passed and those which failed the shock tests at velocities of both  $1000 \pm 15$  ft./sec. and  $1100$  ft./sec. are arranged for purposes of comparison. The data in Table III indicate that at a velocity of  $1100 \pm 15$  ft./sec., hardness rather than shock resistance determines whether plates pass or fail the 57 mm. proof projectile test. The hardness of the passing plates averages  $340 \pm 10$  BHN and that of the failing plates  $320 \pm 7$  BHN, whereas the impact energy of the passing plates at  $-40^{\circ}\text{F}$ . averages  $16.3 \pm 5.8$  ft.lbs. and that of the failing plates  $17.2 \pm 3.5$  ft.lbs. No correlation whatsoever exists between the ballistic and metallurgical shock tests of the 1" thick plates tested at  $1000 \pm 15$  ft./sec., except in the case of the previously described Ordnance Steel Foundry plate of extremely poor shock properties.

7. A further criticism of the 57 mm. proof projectile shock test arises from the fact that some 1" thick cast plates, which upon the basis of metallurgical tests would be considered of inferior quality, passed the shock test at striking velocities of both  $1000$  and  $1100$  ft./sec. American Radiator heat J160 and Symington Gould heat 4375 possess poor shock properties as measured by notched bar impact tests, yet these plates passed the shock test at both striking velocities.

8. The 105 mm. proof projectile shock test of 2" thick cast armor at a velocity of  $1000 \pm 15$  ft./sec. does correlate somewhat better with the metallurgical shock tests in that the passing plates have an average impact energy at  $-40^{\circ}\text{F}$ . of  $35.2 \pm 4.7$  ft.lbs. whereas the failing plates average  $23.5 \pm 2.1$  ft.lbs., see Table IV. No similar correlation was found, however, at a velocity of  $1100 \pm 15$  ft./sec. Of the three plates failing, one has the relatively low impact energy of 26.5 ft.lbs. but the other two failing plates have impact energies higher than those of some of the passing plates.

9. The results of the metallurgical examination show, in general, a very imperfect relation between the ballistic performance of the subject plates and their shock properties. The poor correlation between the ballistic and metallurgical shock tests in combination with the fact that ballistic failures for the most part resulted from Army complete penetrations, demonstrate beyond doubt that the 57 mm. proof projectile shock test for 1" thick cast armor and the 105 mm. proof projectile shock test for 2" thick cast armor as conducted at the Ordnance Research Center do not qualify as bona fide shock tests.

It is possible that these projectiles may yield more satisfactory results at an obliquity where the force of the impact would be spread over a larger area than at normal obliquity.

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M. Yoffa  
Physical Science Aide

A. Hurlich  
A. Hurlich  
Associate Metallurgist

APPROVED:

E. L. Reed  
E. L. Reed  
Research Metallurgist  
Chief, Armor Section

**TABLE I**  
**1" Thick Plates Tested with 57 MM Proof Projectiles**

Company	Heat No.	57 MM Proof Projectile Velocity			Fibre Fracture Rating <sup>a</sup>			V-Notch Charpy Data		
		Ave. BHN <sup>b</sup>	900 ± 15	1000 ± 15	1100 ± 15	P	(shrinkage)	Pt. 108. at +70°F.	Pt. 108. at -40°F.	
American Radiator	J43	334		Passed	Passed	P	(shrinkage)	26.5	28.0	
" "	J160	359		Passed	Passed	Gbf 1/2		22.9	10.6	
Ordnance Steel Dry.	B142	341		Failed <sup>c</sup>		Po 1/4		7.9	4.1	
Pratt & Letchworth	E154	334		Passed	Failed	Po (tr shrinkage)		34.2	15.5	
" "	E157	324		Passed	Failed	P (shrinkage)		24.7	18.1	
" "	E138	311		Passed	Failed	Po 1/8		26.5	17.4	
" "	E162	328		Passed	Failed	P (shrinkage)		45.8	15.8	
" "	E167	328		Passed	Failed	P		17.4	12.1	
" "	E170	318		Passed	Failed	P		43.6	22.5	
" "	E183	334	Passed	Failed		Po 1/8		23.2	13.3	
" "	E186	334		Passed		P (shrinkage)		29.5	13.0	
" "	E188	315		Passed	Failed	Gbf 1/4		28.0	10.6	
Symington-Gould(D)	E719	324		Passed	Failed	Po 1/8		28.0	15.1	
" "	E375	311		Passed	Passed	Po trace		16.4	13.6	
" "	E380	301		Passed	Failed	P (shrinkage)		20.8	16.8	
" "	E3741	299	Passed	Failed		P (shrinkage)		28.8	18.4	
Symington-Gould(R)	E4576	321		Passed	Failed	P		35.8	28.0	

<sup>a</sup>Average of 3 gross-sectional readings.

<sup>b</sup>Steel = fibrous, Po = fibrous matrix with spots of crystallinity. Gbf = bright crystalline patch surrounded by fibrous border. Fractions represent portion of crystalline area.

<sup>c</sup>This plate broke in 3 pieces. All other plates failed because of Army complete penetrations, none had cracking greater than 1/8".

**TABLE II**  
**2" Thick Plates Tested with 105 MM Proof Projectiles**

Company	Heat No.	105 MM Proof Projectile Velocity			Fibre Fracture Rating*			V-Notch Charpy Data		
		Ave. BHN	900 ± 15	1000 ± 15	1100 ± 15	Fo 1/8	Fo 1/4	Fo trace	Ft. Lbs. at +70°F.	Ft. Lbs. at -40°F.
Continental (W)	1367 (Sq. 183)	264	Passed	Passed	Fo 1/8	32.6	35.0			
" "	2508 (Sq. 178)	264	Passed	Failed	Fo 1/4	56.8	37.4			
Continental (C)	5928	253	Passed	Passed	Fo trace	50.1	42.4			
" "	5951	255	Passed	Failed	Fo 1/4	40.7	26.5			
Symington-Gould (D)	3705	250	Passed	Failed	Fo tr (shrinkage)	41.1	42.0			
" "	3719	264	Passed	Passed	Fo trace	29.5	37.4			
" "	3746	253	Passed	Failed	Fo 1/4	24.7	28.0			
" "	4397	245	Passed	Passed	F (shrinkage)	35.2	46.6			
" "	4422	253	Passed	Failed**	Fo 1/10	23.6	23.6			
Union Steel	3734	285	Passed	Failed	Fo 1/2	34.2	20.1			
" "	401A	272	Failed***	Failed***	Fo 1/4 (cracking in excess of 8%)	47.5	22.2			

\*BHN determined at Watertown Arsenal.

\*\*F = fibrous. Fo = fibrous matrix with spots of crystallinity. Fractions represent portion of crystalline area.

\*\*\*Cracking in excess of 8% occurred on these plates as well as Army complete penetrations. All other failing plates failed on Army complete penetrations only.

**TABLE III**  
**Correlation Between Ballistic and Metallurgical Properties**  
**of 1" Thick Cast Armor Shock Tested with 57 MM Proof Projectiles**

Required Velocity - 1000 ± 15 ft./sec.	Required Velocity - 1100 ± 15 ft./sec.
Hardness of Plates Passing the Test	Hardness of Plates Passing the Test
Ave. - $\frac{325}{324} \pm 13$ BHN	
334	334
359	359
334	334
324	334
311	321
326	326
325	326
318	318
315	315
324	324
301	301
321	321
324	324
331	331
321	321
326	326
Ave. - $\frac{321}{326} \pm 10$ BHN	Ave. - $\frac{320}{320} \pm 7$ BHN

TABLE III (cont'd)

Required Velocity -  $1000 \pm 15$  ft./sec.Required Velocity -  $1100 \pm 15$  ft./sec.

Fibre Fracture Rating <sup>a</sup> of Plates Passing the Test	Fibre Fracture Rating of Plates Passing the Test	Fibre Fracture Rating of Plates Passing the Test
F (shrinkage)	Fo 1/4	Fc trace
Gbf 1/2	Fo 1/8	Gbf 1/2
Fo trace	F (shrinkage)	F (shrinkage)
F (shrinkage)	F (shrinkage)	Fo 1/8
Fo 1/8	F	F (shrinkage)
F (shrinkage)	F	F
F	F	Gbf 1/4
F (shrinkage)	F (shrinkage)	Fo 1/8
Gbf 1/4	Fo 1/8	F (shrinkage)
Fo trace	F	F
F (shrinkage)	F	F

<sup>a</sup>F = fibrous.

Fo = fibrous matrix with scattered crystalline patches.

Gbf = Crystalline matrix with fibrous edges.

Fractions after rating refer to the amount of the fractured surface which is crystalline.

TABLE III (Continued)

Required Velocity - $1000 \pm 15$ ft./sec.	
V-Notch Charpy Impact at $-40^{\circ}\text{F}$ . of Plates Passing the Test - Ft.Lbs.	V-Notch Charpy Impact at $-40^{\circ}\text{F}$ . of Plates Failing the Test - Ft.Lbs.
28.0	4.0*
10.6	13.7
15.5	18.4
18.1	Ave. - $11.9 \pm 4.7$
17.4	plate broke in 3 ft.
15.8	
12.1	
22.5	
13.0	
10.6	
15.1	
13.6	
16.8	
28.0	Ave. - $16.9 \pm 4.1$ ft.lbs.

Required Velocity -  $1100 \pm 15$  ft./sec.

V-Notch Charpy Impact at -40° F. of Plates Passing the Test - Ft.Lbs.	V-Notch Charpy Impact at -40° F. of Plates Failing the Test - Ft.Lbs.	V-Notch Charpy Impact at -40° F. of Plates Passing the Test - Ft.Lbs.	V-Notch Charpy Impact at -40° F. of Plates Failing the Test - Ft.Lbs.
26.0	4.1*	26.0	15.5
10.6	13.3	10.6	18.1
15.5	18.4	13.0	17.4
18.1	11.9 ± 4.7 ft.lbs.	13.6	15.8
17.4	Ave. - 16.3 ± 5.8 ft.lbs.	13.6	12.1
15.8	*Plate broke in 3 pieces.	12.1	22.5
12.1		22.5	10.6
22.5		13.0	15.1
13.0		10.6	16.8
			28.0
			17.2 + 3.5

**TABLE IV**  
**Correlation between Ballistic and Metallurgical Properties  
 of 2<sup>8</sup> Thick Cast Armor Shock Tested with 105 MM Proof Projectiles**

Required Velocity - 1000 ± 15 ft./sec.		Required Velocity - 1100 ± 15 ft./sec.	
Hardness of Plates Passing the Test	Hardness of Plates Failing the Test	Hardness of Plates Passing the Test	Hardness of Plates Failing the Test
264	253	264	264
264	253	253	255
253	255	264	250
255	272	248	Ave. - $\frac{256 \pm 13}{2} \text{ BHN}$
250	Ave. - $\frac{266 \pm 13}{2} \text{ BHN}$	257	Ave. - $\frac{256 \pm 5}{2} \text{ BHN}$
264			
248			
Ave. - $\frac{257 \pm 6}{2} \text{ BHN}$			
V-Notch Charpy Impact at -40°F. of Plates Passing the Test - Ft.Lbs.		V-Notch Charpy Impact at -40°F. of Plates Passing the Test - Ft.Lbs.	
35.0	26.0	35.0	37.4
37.4	23.6	42.4	26.5
42.4	20.1	37.4	42.0
26.5	22.2	46.6	Ave. - $\frac{35.3 \pm 5.9}{2} \text{ ft.lbs.}$
42.0	Ave. - $\frac{25.5 \pm 2.1}{2} \text{ ft.lbs.}$		
37.4			
46.6			
Ave. - $\frac{36.2 \pm 4.7}{2} \text{ ft.lbs.}$			

V-Notch Charpy Impact at -40°F. of Plates Passing the Test - Ft.Lbs.		V-Notch Charpy Impact at -40°F. of Plates Passing the Test - Ft.Lbs.	
35.0	26.0	35.0	37.4
37.4	23.6	42.4	26.5
42.4	20.1	37.4	42.0
26.5	22.2	46.6	Ave. - $\frac{35.3 \pm 5.9}{2} \text{ ft.lbs.}$
42.0	Ave. - $\frac{25.5 \pm 2.1}{2} \text{ ft.lbs.}$		
37.4			
46.6			
Ave. - $\frac{36.2 \pm 4.7}{2} \text{ ft.lbs.}$			

TABLE IV (CONT'D)

Required Velocity -  $1000 \pm 15$  ft./sec.

Required Velocity -  $1100 \pm 15$  ft./sec.

Fibre Fracture Rating of Plates Passing the Test	Fibre Fracture Rating of Plates Failing the Test
Fr 1/8	Fr 1/4
Fr 1/4	Fr 1/10
Fr trace	Fr 1/2
Fr 1/4	Fr 1/4 (slightly conchoidal)
Fr trace (shrinkage)	Fr (shrinkage)
Fr trace	Fr (shrinkage)

Fibre Fracture Rating of Plates Passing the Test	Fibre Fracture Rating of Plates Failing the Test
Fr 1/8	Fr 1/4
Fr 1/4	Fr 1/4
Fr trace	Fr trace
Fr 1/4	Fr (shrinkage)

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06-84-ME-OCARMOR BRANCH  
ORDNANCE RESEARCH AND DEVELOPMENT CENTER  
ABERDEEN PROVING GROUND, MARYLANDSUBJECT: Development of a Shock  
Test for 1" and 2"  
Cast Armor.

Report No.: Ar-16646

Sheet 1 of 7

Date of Test: 6 July 1945

Related P.R. No.: AR-5453

Project No.: 2220 (113 Ar3-305)

References: OOM 470.5/APG

910 Feb 45)R SPOME-EE  
APG 470.5/1161OBJECT: To Obtain Shock Test  
Data with the 105 mm  
Proof Projectile on a  
Total of Fifteen 2" Cast  
Homogeneous Acceptance  
Plates Received from  
Gary Proof Range.COMMENTS:

1. Fifteen 2" cast plates, received from Gary Proof Range after passing acceptance tests for penetration, were shock tested with 105 mm proof projectiles in order to obtain data to establish a required velocity for Specification AXB 492.

2. In this test, one round was placed near the center of the plate at a required velocity of 1100 fps (the velocity was corrected for thickness using a correction factor of 5 fps per .01" in thickness). If the plate withstood the impact without excessive cracking or was a Army partial penetration, a second round was fired at a velocity 100 fps higher. If the plate cracked or was a Army complete penetration as a result of the first impact, the second round was fired at a velocity 100 fps lower. Failure was considered to have occurred when cracking extended greater than 8-1/2" and/or Army complete penetration was obtained (light visible through impact).

3. A summary of this test is given on Sheet 2. A list of test facilities is given on Sheet 3. The detailed results are on Sheets 4 through 7.

4. This is the fourth report of test data on this project. Testing is completed and a formal report analyzing all results will be written.

APPROVED:G. G. EDDY  
Col., Ord. Dept.  
DirectorBY:  
(s) C. J. YAGER, MAJ. OD  
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All other plates that failed were on bases of 3-1/2". All specimens in excess of 3-1/2" in diameter were made by our United Foundry and Machine, broken into two pieces due to the process used.

1. Summary of Results		2" Cast Homogeneous Armor									
		15 mm P.E. T-8 - U. S. Quality		Ave.		1000 f.p.s.		Required Velocity + 15 f.p.s.		1200 f.p.s.	
Plate No.	Company	No.	BM	No.	BM	No.	BM	No.	BM	No.	BM
08192-1 Sq 063	Continental Foundry & Mach. (T. I., Ohi.)	8192	259	"	"	"	"	"	"	"	"
82327-2 Sq B48	"	82327	257	266	Passed	"	"	"	"	"	"
08227-2 Sq 064	"	8227	246	"	Passed	"	"	"	"	"	"
08260-2 Sq 065	"	8260	266	"	Passed	"	"	"	"	"	"
82256-1 Sq B46	"	82256	255	255	Passed	Failed	"	"	"	"	"
0-7974-D-277	American Steel & Foundries (O)	7526	251	"	Passed	"	"	"	"	"	"
0-7974-D-256	"	7447	244	"	Passed	"	"	"	"	"	"
0-7974-D-257	"	7454	245	"	Passed	"	"	"	"	"	"
0-7974-D-266	"	7451	246	"	Passed	"	"	"	"	"	"
0-7974-D-261	"	7468	242	"	Passed	"	"	"	"	"	"
8-348	Scullin Steel Co.	1-907	234	"	Passed	Failed	"	"	"	"	"
5-50	"	1-915	232	"	Passed	Failed	"	"	"	"	"
680	"	5-018	251	"	Passed	"	"	"	"	"	"
681	"	5-023	248	"	Passed	"	"	"	"	"	"
682	"	2-177	250	"	Passed	"	"	"	"	"	"

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Report No.: Ar-16646  
Sheet 3 of 7

2. Test Facilities:

a. Guns Used:

Howitzer, Field, 105 mm, M2A1, No. 347, Mfd by Vilter Mfg. Co.

b. Projectiles Used:

Projectile, Proof, T6, 105 mm, Mfd by Frankford Arsenal,  
Lot FA-B-100, Wt. 33.00 lbs.

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 6 July 45  
 ARMOR TEST REPORT NO. AR-16646  
 SHEET 4 OF 7  
 RELATED P.R. NO. AF-5453

RD. NO.	PROJECTILE	S O L I C	G M A C H	REQ. VEL.	ACT. S.V.	P P C P T P	THICKNESS & TYPE	
							RESULTS - ARMOR AND PROJECTILE	
1	Continental Fdry. & Mach. (E. Chi.)						Plate No.: C-8192-1 Sq C63, Heat No.: 8192, BHN 259	
1	105 mm PP T8	0°	2.01	1105	1097	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact	
2	"	"	"	1205	1200	PP(A)	Medium Bulge, .5", 4" Cracks, Mushroomed and Intact	
1	Continental Fdry. & Mach. (E. Chi.)						Plate No. B-2327-2 Sq B48, Heat No.: 2327, BHN 266	
1	105 mm PP T8	0°	1.96	1050	1053	CP(A)	10", 5", 6" Cracks, 18" Crack Through 37 mm Round to Edge of Plate. Mushroomed and Intact	
2	"	"	"	980	967	CP(A)	6", 7", 5", 4" Cracks. Plate Broke into Two Pieces. Mushroomed and Intact.	
1	Continental Fdry. & Mach. (E. Chi.)						Plate No.: C-8227-2 Sq C64, Heat No.: 8227, BHN 246	
1	105 mm PP T8	0°	2.00	1100	1095	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact	
2	"	"	"	1200	1205	PP(A)	3", 3" Cracks, Mushroomed and Intact	
1	Continental Fdry. & Mach. (E. Chi.)						Plate No.: O-8260-2 Sq C65, Heat No.: 8260, BHN 266	
1	105 mm PP T8	0°	2.01	1105	Lost	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact	
2	"	"	"	1205	1208	PP(A)	Large Bulge, No Cracking, Mushroomed and Intact	

CP - Complete Penetration

PP - Partial Penetration

CIP - Core in plate

PUM S - Punching started

BS - Back Spall

FS - Face Spall

SC - Star cracking

DC - Diarecord

TC - cratering

PC - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

PIP PTP - Failed to pass through plate.

ND - Nose destroyed

BD - Base destroyed

NI - Nose intact

BI - base intact

PI - Partial cratering

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 6 July 1945  
ARMOR TEST REPORT NO. AR-16646  
SHEET 5 OF 7  
RELATED P.R. NO. AF-5453

PLATE NO.

HEAT NO.

THICKNESS & TYPE

RD. NO.	PROJECTILE	Q. IN.	S.M. IN.	REQ. VEL.	ACT. S.V.	PP CP PTP	RESULTS - ARMOR AND PROJECTILE
	Continental Fdry. & Mach. (E. Chi.)						Plate No.: B-2256-1 Sq B46, Heat No.: 2256, BMW 255
1	105mm PP T8	0°	2.05	1125	1125	CP(A)	6½", 5½", 5½" Cracks, Mushroomed & Intact
2	"	"	"	1025	1022	PP(A)	3½", 2", 2" Cracks, Mushroomed & Intact
	American Steel Foundries (G)						Plate No.: G-7974-D-277, Heat No.: 7526, BMW 251
1	105mm PP T8	0°	2.01	1105	1104	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
2	"	"	2.05	1225	1222	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
	American Steel Foundries (G)						Plate No.: G-7974-D-256, Heat No.: 7447, BMW 254
1	105mm PP T8	0°	2.02	1110	1112	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
2	"	"	"	1210	1216	PP(A)	5½", 3-1/4", 2½" Cracks, Mushroomed and Intact
	American Steel Foundries (G)						Plate No.: G-7974-D-257, Heat No.: 7454, BMW 245
1	105mm PP T8	0°	2.02	1110	1109	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
2	"	"	"	1210	1211	PP(A)	Large Bulge, No Cracking, Mushroomed and Intact.

CP - Complete Penetration

PP - Partial Penetration

CIP - Core in plate

PUN S - Punching started

BS - Back spall

FS - Face spall

SC - Star cracking

D - Disregard

C - Cratering

P - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

PTP - Failed to pass through plate.

ND - Nose destroyed

NI - Nose Destroyed

NI - Nose intact

NI - Nose Intact

PO - Partial cratering

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Report No.: Ar-16647  
Sheet 3 of 5

2. Test Facilities:

a. Guns Used:

Gun, A.T., 57 mm, M1, No. 726, Mf'd by American Type Founders.  
Tube, A.T., 57 mm, M1, No. 1019, Mf'd by American Type Founders.

b. Projectiles Used:

Projectile, Proof, T1, 57 mm, Mf'd by Andover-Kent Co.,  
Lot AX-3-1, Wt. 6.30 lbs.

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1. Summary of Results:

1" Cast Homogeneous Armor

57 mm PP T1 - 0° Obliquity

Company	Plate No.	Heat No.	Avg. 32% 900 fps	Required Velocity + 15 fps 1000 fps	- 1100 fps
AST - Cast Armor Plant	C26	3560	322	Passed	Failed*
"	C22	3540	326	Passed	Failed
Silver Steel (Chi.)	20B599	20B599	302	Passed	Passed
Scullin Steel Co.	48	3-333	286	Passed	Failed
"	49	5-020	290	Passed	Failed

\*This plate failed due to excess cracking greater than 4-1/2" and Army complete penetration; all other plates failed because of Army complete penetrations (light visible through impact).

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 6 July 45  
ARMOR TEST REPORT NO. Ar-16647  
SHEET 4 OF 5  
RELATED F.R. NO. AF-5453

PLATE NO.	PROJECTILE	C L I P E	A V G E C H E	REQ. VEL.	ACT. S.V.	PP CP PTP	HEAT NO.	THICKNESS & TYPE
	American Steel Foundries						Plate No.: C-26, Heat 3560, BHN 322	
1.	57mm PP T1	0°	1.03	1024	1008	PP(A)	2½", 2½", 2½", 2" Cracks, Mushroomed & intact	
2.	"	"	"	1124	1140	CP(A)	5", 5", 5", 2" Cracks, Mushroomed & intact	
	American Steel Foundries						Plate No.: C-22, Heat No.: 3540, BHN 326	
1.	57mm PP T1	0°	1.00	1000	977	PP(A)	Medium Bulge, 1" Crack, Mushroomed & Intact	
2.	"	"	1.00	1100	1065	CP(A)	4", 3½", 3" Cracks, Mushroomed and Intact	
	Sivyer Steel (Chi.)						Plate No.: 20B599, Heat No.: 20B599, BHN 302	
1.	57mm PP T1	0°	.98	984	983	PP(A)	Large Bulge, Fine Cracking, Mushroomed and Intact	
2.	"	"	.98	1084	1080	PP(A)	2½", 2-1/4" Cracks. Mushroomed and Intact	
	Scullin Steel Co.						Plate No.: 48, Heat No.: 3-333, BHN 286	
1.	57mm PP T1	0°	1.08	1064	1067	PP(A)	Large Bulge, Fine Cracking, Mushroomed and Intact	
2.	"	"	1.08	1164	1165	CP(A)	3½", 3", 2½" Cracks, Mushroomed and Intact	

CP - Complete Penetration

PP - Partial Penetration

CLP - Core in plate

PUN S - Punching started

BS - Back spall

FS - Face spall

SC - Star cracking

D - Disregard

C - Cratering

P - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

FPTP - Failed to pass through plate

ND - Nose destroyed

BD - Base destroyed

NI - Nose intact

BI - Base intact

PC - Partial cratering

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 6 July 1945  
ARMOR TEST REPORT NO. Ar-16647  
SHEET 5 OF 5  
RELATED F.R. NO. AF-5453

PLATE NO.

HEAT NO.

THICKNESS & TYPE

RD. NO.	PROJECTILE	OBLIQ.	AVG. THICK	REQ. VEL.	ACT. S.V.	PP CP PTP	RESULTS - ARMOR AND PROJECTILE
1.	Scullin Steel Co.	0°	1.15	1120	1134	CP(A)	Plate No.: 49, Heat No.: 5-020, BHN 290 3", 3", 3", 2" Cracks, Mushroomed & Intact
2.	"	"	1.15	1020	1070	PP(A)	2", 2", 1-3/4" Cracks, Mushroomed & Intact

CP - Complete Penetration

PP - Partial Penetration

CIP - Core in Plate

PUN S - Punching started

BS - Back spall

FS - Face spall

SC - Star cracking

D - Disregard

C - Cratering

P - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

FPTP - Failed to pass through plate

ND - Nose destroyed

BD - Base destroyed

NI - Nose intact

BI - Base intact

PC - Partial cratering

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C.D. Reg. No.  
06-54-ME-00

ARMOR BRANCH  
ORDNANCE RESEARCH AND DEVELOPMENT CENTER  
ABERDEEN PROVING GROUND, MARYLAND

SUBJECT: Development of a Shock  
Test for 1" and 2" Cast  
Armor.

OBJECT: To Obtain Shock Data  
with the 57 mm Proof  
Projectile on a Total  
of Five 1" Cast Homogeneous  
Plates Received from Gary  
Proof Range.

Report No.: Ar-16647  
Sheet 1 of 5  
Date of Test: 6 July 1945  
Related P.R. No.: AR-5453  
Project No.: 2220 (113 Ar3-305)  
References: OCM 470.5/APG  
(10 Feb 45)SPONME-KB  
APG 470.5/1161

COMMENTS:

1. Five 1" cast plates, received from Gary Proof Range after passing acceptance tests for penetration, were shock tested with the 57 mm proof projectile in order to obtain data to establish a required velocity for Specification AX3 492.

2. In this test, one round was placed near the center of the plate at a velocity of 1000 fps. The velocity was corrected for thickness using a correction factor of 8 fps per .01" in thickness. If the plate withstood the impact without cracking excessively or was a Army partial penetration, a second round was fired at a velocity 100 fps higher. If the plate cracked excessively or was a Army complete penetration on the first impact, the second round was fired at a velocity 100 fps lower. Failure was considered to have occurred when cracking extended greater than 4-1/2" (two calibers) and/or an Army complete penetration was obtained (light visible through impact).

3. A summary of this test is given on Sheet 2. A list of test facilities is given on Sheet 3. The detailed results are on Sheets 4 and 5.

4. This is the third report of firing data on this project. Testing will continue.

APPROVED:

BY:

G. G. EDDY  
Col., Ord. Dept.  
Director

(s) C. J. Yaeger, Maj. OD  
for STUART McLAIN  
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Acting Chief, Arms &  
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 ARMOR BRANCH

DATE OF FIRING 6 July 1945  
 ARMOR TEST PROJECT NO. Ar-16646  
 SHEET 7 OF 7  
 RELATED P.N. NO. AP-5453

Rd. No.	PROJECTILE	S. HLD.	W. HLD.	THICK. IN.	S.D. VEL.	ACT. S.V.	PP CP PTP	PLATE NO.		HEAT NO.	THICKNESS & TYPE
								RESULTS - ARMOR AND PROJECTILE			
1	Scullin Steel Co. 105mm PP TS	0°	2.00	1100	1109	CP(A)	Plate No.: 680, Heat No.: 5-018, BHN 251 9-1/4", 6", 6", 4" Cracks, Mushroomed & Intact				
2	" "	0°	2.00	1000	989	PP(A)	Medium Bulge, No Cracking, Mushroomed & Intact				
1	Scullin Steel Co. 105mm PP TS	0°	2.05	1125	1136	CP(A)	Plate No.: 681, Heat No.: 5-023, BHN 248 6½", 4½", 3½" Cracks, Mushroomed & Intact				
2	" "	0°	2.05	1025	1022	PP(A)	3½", 2", 2" Cracks, Mushroomed & Intact				
1	Scullin Steel Co. 105mm PP TS	0°	2.02	1110	1118	CP(A)	Plate No.: 682, Heat No.: 2-177, BHN 250 5½", 4½", 2½" Cracks, Mushroomed & Intact				
2	" "	0°	2.02	1010	1021	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact				

CP - Complete Penetration  
 PP - Partial Penetration  
 CIP - Core in plate  
 PUS S - Punching started  
 BS - Back spall  
 FS - Face spall  
 SC - Star cracking  
 D - Disregard  
 C - Cratering  
 P - Petaling on face

PIP - Passed through plate  
 PIP - Projectile in plate  
 NPTP - Failed to pass through plate.  
 ED - Nose destroyed  
 BD - Base destroyed  
 NI - Nose intact  
 BI - Base intact  
 PC - Partial cratering

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ABERDEEN PROVING GROUND, MARYLAND  
ARMOR BRANCH

DATE OF FIRING 6 July 1945  
ARMOR TEST REPORT NO. Ar-16646  
SHEET 6 OF 7  
RELATED P.R. NO. AP-5453

RD. NO.	PROJECTILE	HEAT NO.				PP CP PTP	RESULTS - ARMOR AND PROJECTILE
		SHG	SHF	REQ. VEL.	ACT. S.V.		
	American Steel Foundries (G)						Plate No.: G-7974-D-266, Heat No.: 7451, BHM 246
1	105 mm PP TS	0°	2.04	1120	1126	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
2	"	"	2.09	1245	1243	PP(A)	4½", 2½", 2" Cracks, Mushroomed and Intact
	American Steel Foundries (G)						Plate No.: G-7974-D-261, Heat No.: 7463, BHM 242
1	105 mm PP TS	0°	2.00	1100	1119	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
2	"	"	"	1200	1205	PP(A)	Large Bulge, 2½", 2" Cracks, Mushroomed and Intact
	Soullin Steel Co.						Plate No.: S-48, Heat No.: 1-907, BHM 234
1	105 mm PP TS	0°	1.92	1060	1064	CP(A)	5½", 4½", 3½" Cracks, Mushroomed and Intact
2	"	"	"	960	947	PP(A)	2½", 2-1/4" Cracks, Mushroomed and Intact
	Soullin Steel Co.						Plate No.: S-58, Heat No.: 1-915, BHM 232
1	105 mm PP TS	0°	2.03	1115	1025	PP(A)	Medium Bulge, No Cracking, Mushroomed and Intact
2	"	"	"	1215	1200	PP(A)	Large Bulge, No Cracking, Mushroomed and Intact

CP - Complete Penetration

PP - Partial Penetration

CIP - Core in plate

PUS - Punching started

BS - Back spall

FS - Face spall

SC - Star cracking

D - Disregard

C - Cratering

P - Petaling on face

PTP - Passed through plate

PIP - Projectile in plate

PTPF - Failed to pass through plate.

ND - Nose destroyed

BD - Base destroyed

NI - Nose intact

BI - Base intact

PC - Partial cratering

||||||| RESTRICTED |||||||